POWER

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The Prime Movers' Committee

WHEN the history of the electrical station as an engineering evolution shall be written, it is not the files of the contemporaneous press nor the notebooks of current practitioners that shall furnish the record of its struggles and achievements, but the Reports of the Prime Movers' Committee of the National Electric Light Association.

This is, without doubt, the most important annual contribution to the subject of power-plant engineering; the feature of the literature of the subject that is looked for with most interest by all who have to do with the design and operation of power plants.

It has, as a source to draw upon, the wealth of experience of the member companies of the N. E. L. A., who are so circumstanced, with regard to this document and the committee that produces it, that they can discuss with the utmost frankness the results that have followed upon the adoption of any plan or the use of any apparatus or material.

The manufacturers of power-plant devices and supplies deem it a privilege to contribute to the Report the latest development in the lines upon which they are in a position to speak as specialists, and their utterances often give glances at the picket lines of advance.

The ordinary crying of wares has no chance with this audience.

For the past several years the Report has been an embarrassment of riches. A volume of several hundred pages was loosed at the membership a few days before the Spring Meeting, and nobody was ready to discuss it intelligently when the session devoted to its presentation came.

This year the committee announces a new plan which is bound to be an improvement. For the present meeting the report is in two parts, not so voluminous collectively as the report of last year; but when the new plan is in complete operation, the reports of from two to five subcommittees will appear at one time as a single pamphlet, and these pamphlets will be issued at fairly regular intervals through the year.

Although much of the material may have lost its novelty by the time of the annual meeting, the points that are open to debate and that will gain most from discussion, will probably get more attention after mature consideration than they have had when launched without opportunity for study and the assembling of related material.

Our tribute to the Committee. May its good work continue in the broad spirit of searching for engineering truth and making it known.

FIG. 1—AIRPLANE VIEW OF MARYSVILLE STATION AND SITE

New Marysville Plant, Detroit Edison Co.

By C. HAROLD BERRY
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THE territory served by the Detroit Edison Company falls roughly within a semicircle with a radius of 50 or 60 miles, the City of Detroit occupying the region immediately around the center, with a radius of some 5 miles. The diameter of this semicircle lies along the Detroit River, Lake St. Claire and the St. Claire River, reaching Port Huron on the north and Monroe on the south. The two older stations, Delray and Connors Creek, are on the Detroit River, four or five miles from the center of the city, Delray to the south and Connors Creek to the north. In order to reduce transmission losses and care for the growth of load, a third plant has been constructed at Marysville, at the northern end of the system, on the St. Claire River, near the City of Port Huron. In the present section of the Marysville plant are two turbo-generators, one of 10,000 kw. and the other of 30,000 kw. capacity, served by four boilers, each having 28,212 sq.ft. of effective heating surface. This section of the building has been designed to accommodate a third unit, of 10,000 kw. capacity, which will be installed as the demand grows. The boiler equipment is considered adequate for 50,000 kw. of turbo-generator capacity.

From the illustration, Fig. 1, a general idea will be obtained of the plant site and from Fig. 3 the arrangement of the station will be evident. The site of the building straddles the bed of a creek, and the turbine room is in the creek bed, flanked on either bank by the boiler house on one side and the switch house on the other. This places the heaviest weight at the lowest point and reduces any tendency of the foundation to slide on the clay which supports it. Beneath the turbine room are three canals—one for incoming cooling water, one for outgoing cooling water and one to carry the water of the creek. In cases of extreme high water the creek channel may overflow into the cooling-water discharge canal, but judging from records of stream flow, this will seldom occur. It may appear at first sight that the creek should have been led directly into the discharge canal, but this was not desired because it is planned to combat ice by recirculating the warm water from the discharge canal into the intake canal ahead of the screen and trash racks and, in extreme cases, behind the screens. In such cases the débris carried by the creek would be objectionable.

As indicated in Fig. 4, the turbines are placed with their axes lengthwise and on either side of the room, so that when the plant is completed there will be two rows of units, staggered to provide open passes for connections from each machine to the boiler and switch houses. The turbines are impulse machines designed for a throttle pressure of 275 lb. gage and an initial steam temperature not exceeding 700 deg. F. The first unit is a 9-stage 10,000-kw. 1,800-r.p.m. turbine with gang valve governing. The second unit is a 17-stage 30,000-kw. 1,800-r.p.m. turbine with a governor-controlled throttle and overload valve.

Along the boiler-house side of the turbine room are the boiler-feed pumps and house turbo-generators. There are three boiler-feed pumps, each of 1,200 gal. per min. capacity, two driven by direct-current motors and one, a stand-by, driven by a steam turbine. The house turbine is of 2,000-kw. capacity, and only one has thus far been installed, a second being on order.

At the west end of the turbine room on the boiler-room side is the central gage board, at which the operating engineer will make his headquarters.

On the wall opposite the central gage board is one of a series of plant indicating groups, comprising a Warren clock, a plant-load indicator and a machine

on-and-off indicator. Instead of the usual clock movement the Warren clock employs a small synchronous motor to drive the hands through a worm gear train. The load indicators throughout the plant are large milliammeters connected in series, with their scales graduated on the job to give identical readings. A series resistance varies the current, under the control of a totalizing wattmeter. The machine on-and-off indicators are simply a group of metal boxes with ground-glass fronts bearing machine numbers. A white light indicates machines on the line; no light, machines down; a red light, machines in transition.

In the same wall of the turbine room is a large bay window through which the electrical operators in the switchboard control room can see the turbine-room floor and, if regular signals fail, can employ manual sign language.

North of the turbine room is the switchhouse. On the ground level are found the main and auxiliary transformers, and certain auxiliary systems switch gear.

In the turbine-room basement, or condenser room, are the main condensing equipment, general service pumps, air compressors, etc. The condensers are of the surface type, with 14,100 sq.ft. of surface for the 10,000-kw. unit (1.41 sq.ft. per kw.) and 30,350 sq.ft. for the 30,000-kw. unit (1.01 sq.ft. per kw.). The larger condenser was designed to give uniform steam velocity from top to bottom, and to this end variable tube spacing, as used for many years in England, was adopted with certain modifications. The tubes are 1 in. in outside diameter and have 20 ft. of effective length. The condenser comprises two more or less distinct parts: a steam-condensing section and an air-cooling section. The lowest bank of tubes in the steam section are to be blanked off in winter, to avoid excessive cooling of the condensate. The entire bottom of the condenser shell is the hotwell; there is no special depression for collecting condensate. Water leaves this shell to enter a cylindrical tank from which the hotwell pumps remove it. Turbine casing drains are carried to this tank and thus heat the condensate somewhat. All openings into and out of this tank are tangential, so that the contained water whirls, and thus mixes thoroughly. The top of the tank is vented to the condenser shell to permit the egress of any air that may be liberated. Since tests of this condenser are as yet uncompleted, it is perhaps not wise to go further into the details of design and construction.

The 10,000-kw. condenser is of the two-pass type served by a single 20,000-gal.-per-min. centrifugal circulating pump, while the 30,000-kw. condenser is single-pass and served by two 40,000-gal.-per-min. pumps, either or both of which may be operated.

The hotwell pumps are of the two-stage type, with a special form of first-stage impeller suitable for operation with a small suction head. The capacity of this pump is unusually sensitive to changes in suction head. For a change in level of condensate in the condenser shell or hotwell of less than 2 ft., the pump capacity varies over the entire range of steam flow through the turbine.

Four Stirling, type W boilers have been installed, each having 28,212 sq.ft. of effective heating surface, together with 3,168.6 sq.ft. of superheater surface (11.23 per cent). Each boiler is served by a double-ended 22-tuyere, three-ram Taylor stoker, with 14 retorts at each face of the boiler. The drive is of a type recently developed, using two-speed power boxes.

Each boiler is served by an individual forced-draft fan designed to give 103,000 cu.ft. of air per minute at a static discharge pressure of 7.25 in. of water. For each pair of boilers there is a spare blower, available for either boiler of the pair, but not for both at once. Each boiler also has an induced-draft fan which discharges gas to the base of an individual stack, 80 ft. high above the roof.

The boilers are set high, the mud drum centers being 18 ft. 9 in., and the steam drum centers 39 ft. 8 in. above the firing floor.

Those who are familiar with this type of boiler will recognize several changes in design in the Marysville installation. There are fewer tubes in the front, or

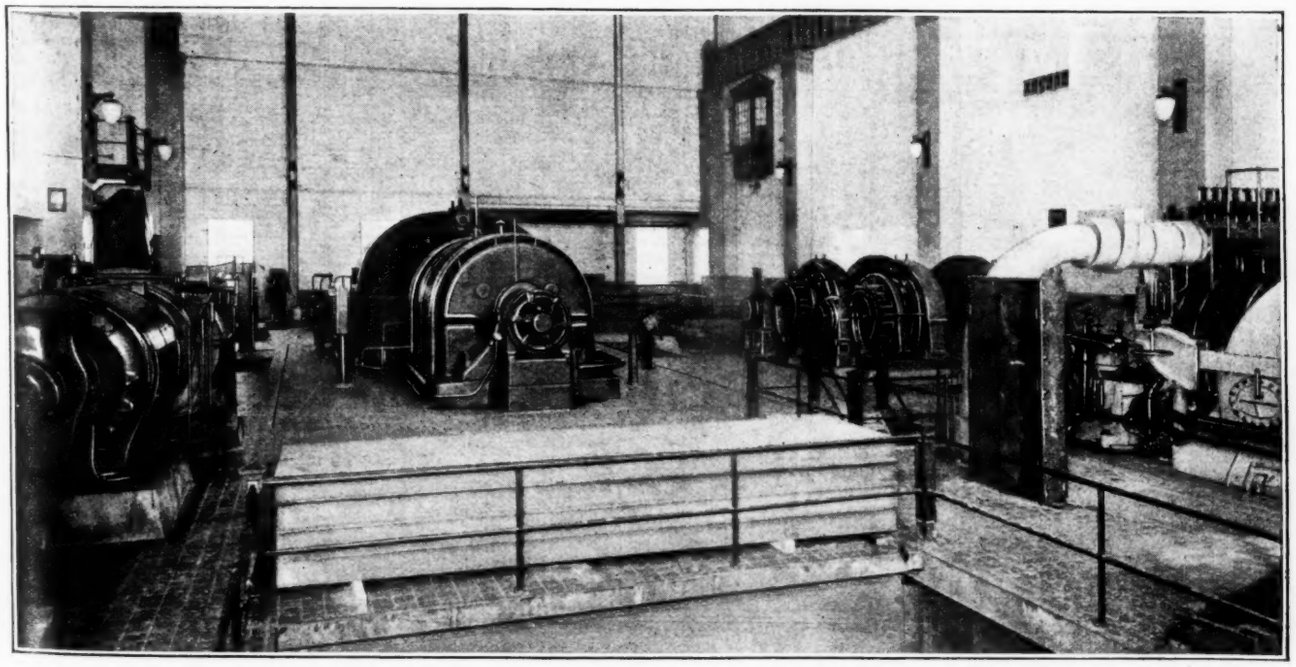

FIG. 2—TURBO-GENERATOR ROOM

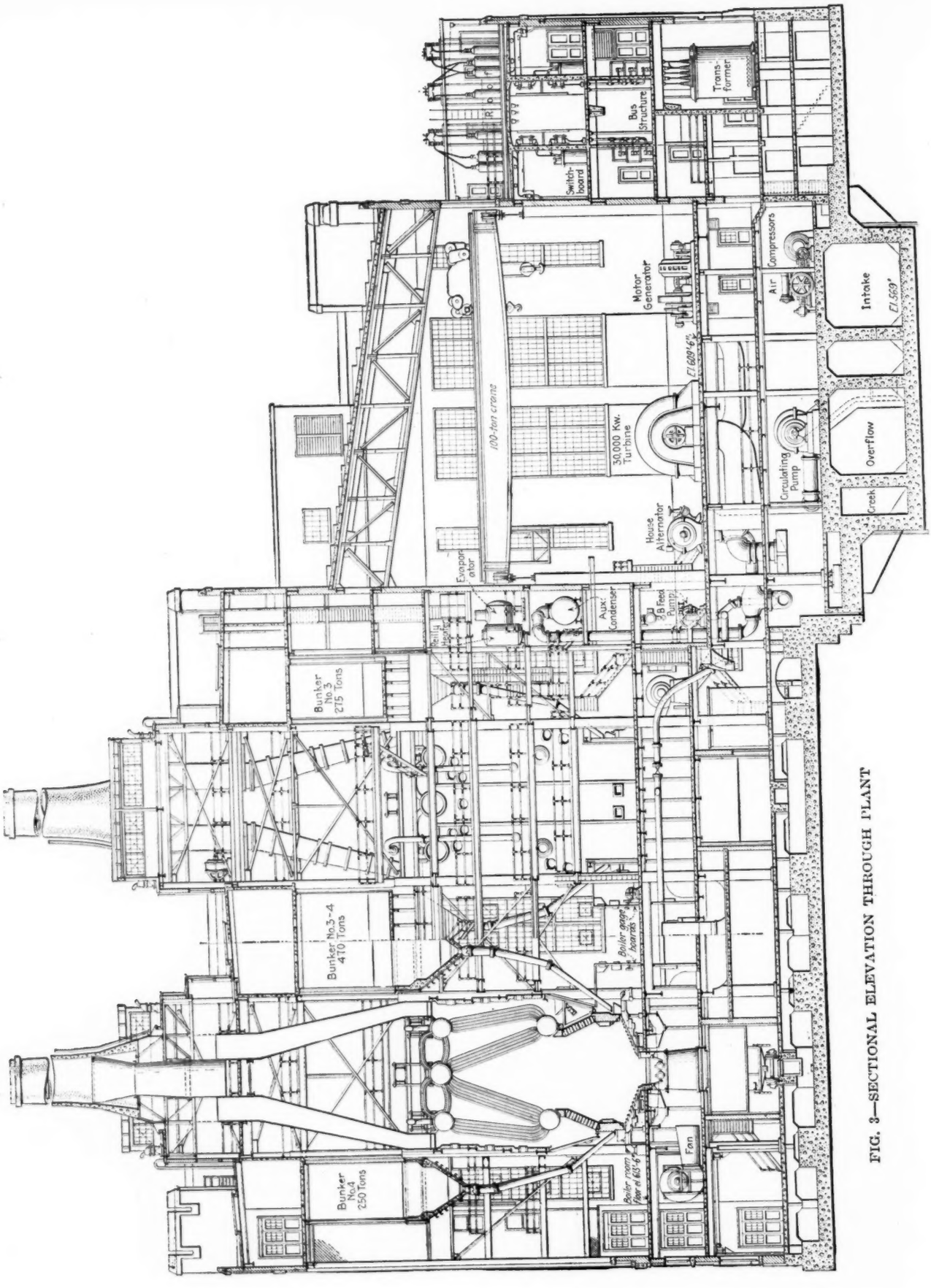

FIG. 3—SECTIONAL ELEVATION THROUGH PLANT

inner, banks, and more in the back, or outer. The back banks are baffled for three gas passes. This design was the outgrowth of a series of tests conducted during the summer of 1921 at the Connors Creek plant.[1]

The furnace is 19 ft. 4½ in. by 26 ft. 7 in. between walls, giving a gross area of 515 sq.ft. The projected area of active stoker surface is 392.1 sq.ft. The total furnace volume is approximately 9,727 cu.ft. For this section of the plant the ratios in Table I hold for the four boilers now in and the three turbines (50,000 kw. aggregate) for which this section has been built. Space has been left above the boilers for economizers, should it develop that they are desirable.

The stokers are equipped with two-roll clinker grinders which discharge refuse into an ashpit from which it is dumped into steel railroad cars. These pits are fitted with sliding gates driven by compressed-air cylinders.

Coal is received by rail, for the present, in two hoppers below ground level, from which it is carried by two inclined pan conveyors to two coal crushers in a room in the southeast corner of the boiler house. The crushed coal is discharged to two bucket elevators carrying the coal to the bunker room and delivering it to either of three belt conveyors which distribute it to the three bunkers running lengthwise of the boiler house.

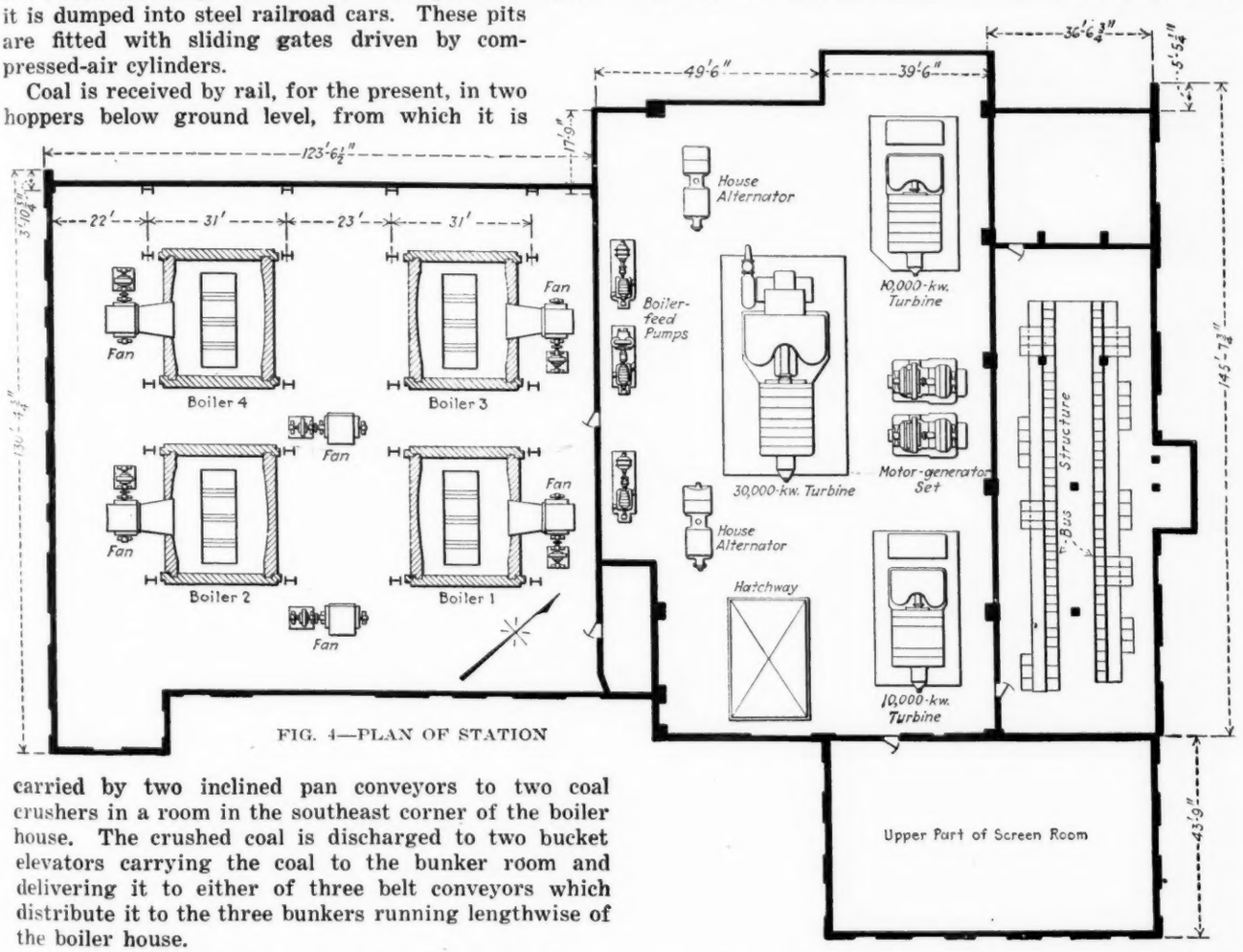

FIG. 4—PLAN OF STATION

TABLE I—RATIOS FOR PRESENT FOUR BOILERS AND THEIR CONNECTED TURBINES

Kw. per 10 sq.ft. of boiler heating surface	4.43
Kw. per stoker retort	446.4
Kw. per stoker tuyere	20.3
Kw. per cubic foot of furnace volume	1.29
Kw. per square foot of projected active stoker area	32.0

With the exception of one stand-by boiler-feed pump and one stand-by general service pump, all auxiliaries are motor driven. The stand-by pumps are turbine driven. Those auxiliaries whose uninterrupted running is essential to the continuous operation of the plant are connected to a special bus, which is safeguarded in several ways.

Other auxiliaries, such as coal-handling equipment, that may be shut down for hours without seriously jeopardizing plant reliability, are driven from a house alternating-current bus for which only the usual protection is provided. The diagram, Fig. 7, indicates the auxiliary power electrical layout for several house-turbine and motor-generator units. At present only one house turbine unit and two motor-generators are installed.

Each house turbo-alternator and motor-generator set can be connected in a variety of ways, as indicated in Fig. 7. In the diagram the house turbo-alternator *A* is running in synchronism with the main units. When a small machine is thus operated in parallel with much larger generators, the small unit is often subject to wide and erratic variations in load and possibly to severe overloads. To prevent this, the practice at Marysville will be to set the governor of the small machine for a frequency slightly higher than that of the system. Since this small machine is running synchronized with an extensive system, its speed cannot exceed system frequency. The governor being set for a higher speed, the governor steam valve will be wide open. The load on the turbine then may be controlled and varied at will by the hand-operated throttle valve. Should the system connection open or should the house machine switch open, the governor will act as soon as the speed has risen to that for which the governor is set.

At *B* the house turbo-alternator is driving its

[1] See paper presented at the 1922 annual meeting of the American Society of Mechanical Engineers, by P. W. Thompson. An abstract of this paper appeared in *Power*, Jan. 23, 1923, pp. 128-131.

motor-generator set directly, thus giving a source of direct-current power independent of the main units.

With the *C* switching arrangement the motor-generator is driven from the house alternating-current by power derived from the main station bus From the diagram it would appear that the house turbo-alternator at *A* is also helping to drive the motor-generator at *C;* actually, however, connections *A* and *C* are not ordinarily expected to occur at the same time.

At *D* is shown a combination in which power is flowing to or from the main system according as the output

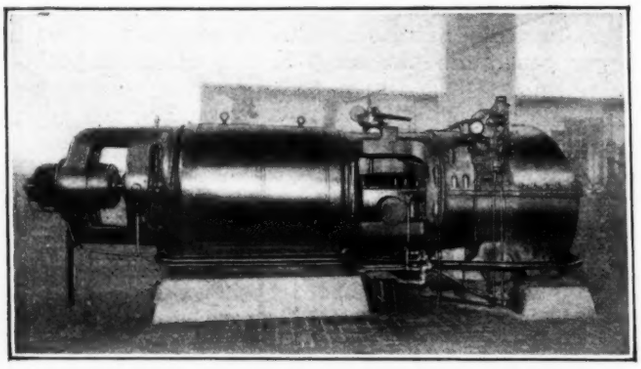

FIG. 5—ONE OF THE HOUSE TURBO-GENERATORS

of the house turbo-alternator (set by hand throttle as in *A*) is greater or less than the load on the motor-generator set. It is not expected that this connection will be used except as a transition.

As a further safeguard to continuous service on the house direct-current bus there is a 240-volt floating storage battery having a one-hour discharge rate of 1,500 amperes. This is equivalent to 1,000 kw. for about 20 minutes. Not only does this battery serve as an excellent voltage stabilizer; it would serve to keep the direct-current bus alive should the main bus fail, stopping motor-generator sets connected as at *C*, Fig. 7. It is planned to operate enough units connected as at *B*, so that they, together with the storage battery, will be adequate to carry the plant auxiliaries for a period ample for starting another machine or otherwise clearing up the situation.

In short, the house-service alternating-current bus has two sources of power—(1) the main system and (2) the house turbines. The house-service direct-current bus has three sources—(1) the main system, (2) the house turbines and (3) the storage battery. This use of several sources, together with suitable protective devices, makes the house direct-current service reliable to a high degree. It is fitting that such exceptional precautions be taken, since the reliability of the entire system depends on the continuous operation of power-plant auxiliary machinery. As a last resort there are stand-by steam-driven boiler-feed and general-service pumps.

It is fitting at this point to call attention to the fact that the house-turbine load is not dependent on the power required by station auxiliaries. House turbines connected as at *A*, Fig. 7, and motor-generators connected as at *C* make it possible to transfer to or from the main bus any desired power up to the capacity of the apparatus and connections. A house turbine connected as at *A*, is delivering energy at any desired constant rate to the main bus, in parallel with the much larger main units, and is also helping to carry the house-service alternating-current load (including the motor-generators connected as at *C*) in whole or in part.

The flow of energy to or from the main bus will vary with the auxiliary power demand, but this relatively small variation can be absorbed easily by the main generating units. Whatever the auxiliary power demand a house turbine connected as at *A* may be considered to be delivering its entire output to the main bus, in parallel with the main turbo-generators, for if this house turbine were shut down, the main units would have to take up its full output. In other words, the generating system of a plant equipped with house turbines comprises both large and small generators, together serving an aggregate load, part of which chances to be within the station. The small turbo-generators are used expressly to give exceptionally reliable service for the operation of plant auxiliaries, and for this reason they are connected and operated in rather special ways.

Fig. 8 shows diagrammatically the auxiliary steam and feed-water heating system. The house turbines exhaust into a header from which risers conduct the steam to surface condensers through which condensate from the main units is circulated on its way to the hot boiler-feed tanks. Each auxiliary condenser is served by an air cooler, which is in effect a small surface condenser through which the cold condensate is passed before it enters the auxiliary condenser. Air and vapor from the auxiliary condenser pass to the air cooler, where much of the vapor is condensed, the air and residual vapor passing to a suction header served by

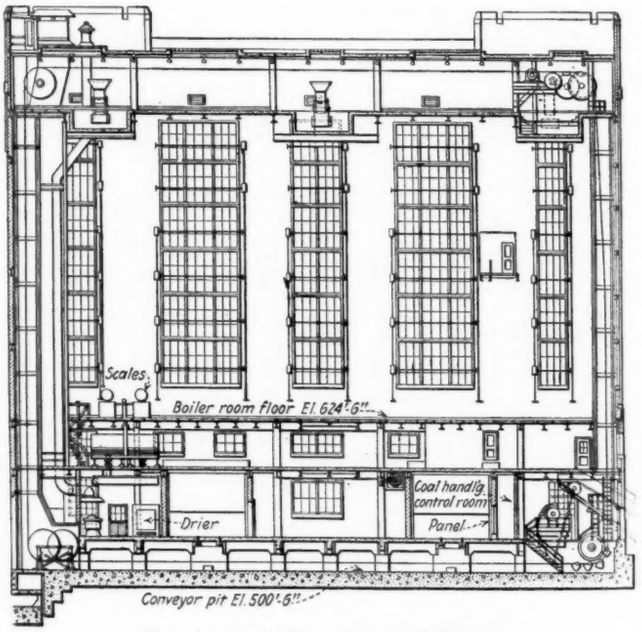

FIG. 6—BUCKET COAL CONVEYOR

two auxiliary dry-vacuum pumps. The air cooler drips into the auxiliary condenser, from which condensate is removed by a centrifugal hotwell pump discharging to the hot boiler-feed tank.

From the hot boiler-feed tank, water is taken by the boiler-feed pumps, which discharge to duplicate headers, main and stand-by. The feed to the stand-by header is direct; that to the main header passes through a tubular heater, in which the water is heated by steam drawn from the steam shaft seals at the high-pressure ends of the main turbines, together with the vapor

generated in the second-effect makeup evaporators. These heaters, as well as both effects of the evaporator plant, drip through traps to the hot boiler-feed tanks.

Steam drawn from the main turbine shaft seals is highly superheated, perhaps 400 deg. F., but experience indicates that desuperheating is unnecessary, owing

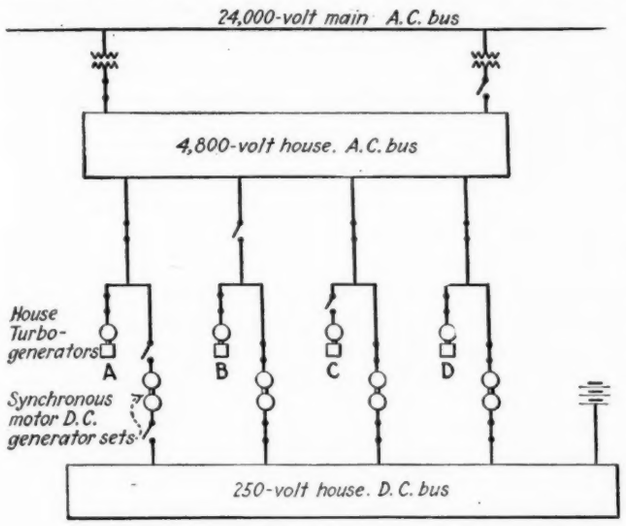

FIG. 7—AUXILIARY ELECTRICAL LAYOUT

probably to the fact that the heaters were designed for a restricted water-pressure drop, so that the heating surface is somewhat larger than otherwise would be provided.

It has been planned to carry an absolute pressure of 14 in. of mercury in the auxiliary condensers and a pressure of 10 in. in the auxiliary dry-vacuum-pump suction header. The drop of 4 in. occurs in the air cooler, which is fitted with closely spaced baffles resembling the blades of an ordinary electric fan. Thus, at the expense of a large pressure drop, the air and vapor are caused to scrub the cooling surface vigorously, with correspondingly effective cooling.

The auxiliary condenser is expected to heat the water to within three or four degrees of the temperature corresponding to the pressure (14 in. = 176 deg.), that is, to about 172 deg. F. This water passes to the hot tanks, where it is further heated, though only slightly, by the various drips entering these tanks. Passing through the boiler-feed pumps, the water enters the heaters, in which it is heated some 20 to 30 deg. by steam from the main unit shaft seals and the second-effect evaporator vapor.

Covered by tight tops vented to atmosphere, the hot tanks are lagged all over to minimize heat loss. Drips that are hotter than 212 deg. are introduced through the top of the tank, with the expectation that they will furnish sufficient steam to blanket the water with an atmosphere virtually air-free, thus reducing the likelihood of air being dissolved by the water to an appreciable extent.

It perhaps may be asked why the steam from the main turbine shaft seals and from the second-effect evaporators was not introduced into the auxiliary exhaust header and thence to the auxiliary condensers, as was done in the original Connors Creek layout. This would eliminate one set of heaters, but the disadvantages are serious, from the viewpoint of thermal economy and operating convenience.

From the viewpoint of thermal economy the whole matter hinges on the effect on the steam rate of the house turbine. The situation, in brief, is this: There is a definite quantity of water to be heated, and the final temperature of that water is rather well established. That is, a fixed quantity of heat can be absorbed. This heat is furnished by steam issuing from the exhaust of the house turbines and from evaporators, shaft seals, etc.

If, on the other hand, these steam quantities are separated and the exhaust from the house turbines is condensed in a primary condenser, the water will leave this heater at some temperature lower than its final temperature. The pressure prevailing in this heater therefore will be lower than it would be if all the steam were introduced into it. With lower exhaust pressure the house turbine will have a lower steam rate, so that for the same flow of steam more energy will be generated. The final water temperature will be unchanged, since the remaining steam is condensed by the same water in a secondary heater following the auxiliary condenser. The net result is an increase in thermal economy of the station, an end plainly desirable provided the extra apparatus called for does not entail fixed charges which overbalance the generating economy.

From the viewpoint of operating convenience the separation of turbine exhaust and steam from other sources is highly desirable. If, for example, evaporator vapor is mixed with turbine exhaust, the two passing to a common condenser, any change in the rate of steaming of the evaporators will upset the balance in this condenser, changing the pressure and hence the output of the house turbine. The vacuum may be lost altogether. In any event a complete readjustment of

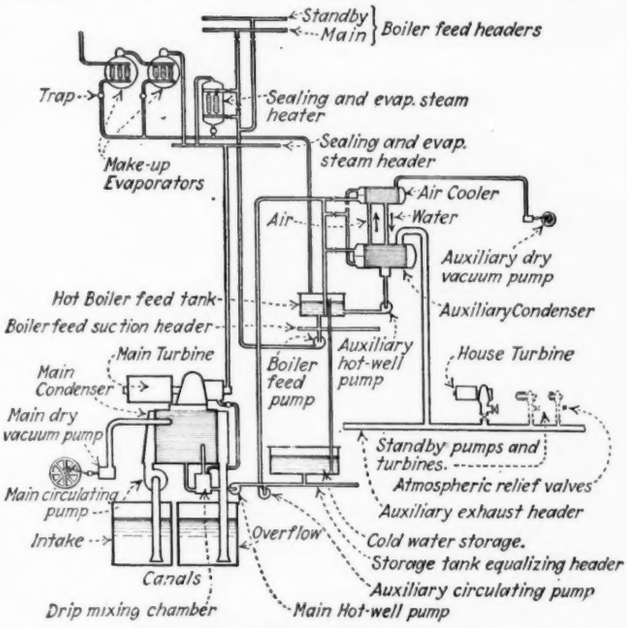

FIG. 8—AUXILIARY THERMAL SCHEME SHOWING FEED-WATER HEATING SYSTEM

the house-turbine loading must be made. Main turbine shaft seals, makeup evaporators and house turbines follow different schedules in the quantities of steam they discharge and are controlled on the basis of entirely different considerations. Mixing them together so that they mutually influence one another leads to distinct inconvenience, with occasional actual disturbances.

Operation is much simpler if the steam from the three sources indicated is separated.

Those who are familiar with the heat-balance system of the Connors Creek plant, will recognize the same general scheme in the Marysville layout, with a few significant changes. Since their functions are substantially identical, the cold tanks and surge tanks of Connors Creek have been combined in the Marysville storage tanks. The barometric jet condensers of Connors Creek have been displaced by auxiliary surface condensers with air coolers, simply because experience indicates that water passing down the tail pipe of a jet condenser carries more air in solution than the entering water, which is almost air-free. Surface condensers served by adequate vacuum pumps have shown themselves to be effective deaërators. The heaters that condense steam from the main turbine shaft seals and from the second-effect evaporators had no counterpart in the original Connors Creek arrangement, but such heaters have been installed there recently with satisfactory results.

The Marysville plant began regular operation on Nov. 1, 1922. The over-all results obtained thus far indicate economies in fair accord with what reasonably might be expected from a plant of this design during its early days. It has not yet been possible to load the station to much more than half its capacity, owing to limitations imposed by the transmission system.

The author wishes to express his indebtedness to C. M. Weinheimer and R. B. Purdy, engineers with the company, for their assistance in compiling and checking the material presented in this article.

DATA ON MECHANICAL EQUIPMENT OF MARYSVILLE PLANT OF THE DETROIT EDISON CO.

BOILERS AND SUPERHEATERS

Manufacturer of boilers	Babcock and Wilcox Co.
Number of boilers	4
Water-heating surface per boiler, sq.ft.	28,212
Boiler working pressure, lb. per sq.in.	300
Total temperature, deg. F.	700
Superheater surface, sq.ft.	3,168.6
Ratio of superheater surface to boiler heating surface, per cent	11.23

FORCED-DRAFT FANS

Manufacturer	American Blower Co.
Number	6
Type	No. 9 Sirocco double inlet fan
Speed, r.p.m.	525
Capacity, cu.ft. per min. at 7.25 in. static pressure	103,000
Drive	Direct connected to adjustable speed d.c. motor

INDUCED-DRAFT FANS

Manufacturer	Buffalo Forge Co.
Number	4
Type	No. 11 double-inlet, double-width, Niagara Conoidal
Speed, r.p.m.	835
Capacity, cu.ft. per min. at 370 deg. F., 8.4 in. static pressure	136,500
Drive	Direct connected to d.c. motor

STOKERS

Manufacturer	American Engineering Co.
Kind	Double-ended Taylor underfeed
Width of grate, ft.-in.	24—7
Length of each grate, projected, in.	82
Number of stokers per boiler	2
Grate area, projected, sq.ft.	392.1
Ratio of water-heating surface to grate area	72 to 1
Drive	Adjustable speed d.c. motor; two-speed gear boxes
Coal	West Virginia semi-bituminous
Moisture	4.58
Ash (dry basis)	12.73
Heat value (dry basis), B.t.u.	13,000

BOILER SETTINGS

Height of center mud drum from floor, ft.-in.	18—9
Volume of combustion chamber, cu.ft.	9,727
Volume of combustion chamber per sq.ft. of projected grate area, cu.ft.	24.8
Arches	None

STACK

Type	Self-supported steel stack
Boilers per stack	1
Inside diameter at top, ft.	9
Height above grate, ft.	175
Area of chimney inside at top, sq.ft.	63.6
Ratio of chimney area to grate area	0.162

TURBO-GENERATOR

Rating, kw.	10,000	30,000
Manufacturer	General Elec. Co.	General Elec. Co.
Number of units (present section)	2	1
Type	Curtis	Curtis
Number of stages	9	
Speed, r.p.m.	1,800	1,800
Generator	3-ph. 60-cyc. 4,800-v.	3-ph. 60-cyc. 12,200-v.
Exciter, direct-connected, voltage	250	250
Rating, kw.	75	140

Guaranteed performance: Operating conditions, 275 lb. gage, 235 deg. superheat, for 10,000 kw. and 700 deg. total temperature for 30,000 kw.; 29 in. vacuum for both.

10,000 Kw.		30,000 Kw.	
Kw. Output of Generator	Lb. of Steam per Kw.-Hr.	Kw. Output of Generator	Lb. of Steam per Kw.-Hr.
5,000	11.45	15,000	10.3
7,500	10.75	20,000	9.85
10,000	10.65	26,000	9.70
		30,000	9.85

CONDENSERS

Manufacturer—No. 1 designed by Detroit Edison Co., built by Russell Wheel & Foundry Co.
No. 2 built by Worthington Pump & Machinery Corporation.

	No. 1	No. 2
Surface, sq.ft.	14,100	30,350
Surface per kw. of generator rating	1.41	1.01
Circulating pump capacity, gal. per min.	20,000	80,000
Drive, direct connected adjustable speed d.c. motor		
Speed, r.p.m.	400	340
Hotwell pump capacity, gal. per min.	300	800
Drive, direct connected d.c. motors	Constant speed	Adjustable speed
Speed, r.p.m.	1,150	1,150
Air pump capacity, displacement cu.ft. per min. free air	.....	2,050
Type	Rotative d.v. pump, two-stage	
Drive	Direct connected d.c. motor	

HOUSE TURBO-ALTERNATOR

Manufacturer	General Electric Co.
Number (present section)	2
Capacity, kw.	2,000
Generator	3-ph. 60-cycle 4,800-v.
Condenser, sq.ft.	3,475

FEED-WATER HEATERS

Number (present)	2
Type	No. 86 Reilly
Manufacturer	Griscom-Russell Co.

AUXILIARY CONDENSERS

Number (present)	2
Type	Surface, with external air coolers
Manufacturer	Griscom-Russell Co.
Size, sq.ft.	3,475
Capacity, lb. water per hr. from 85 to 171 deg. F.	475,000

EVAPORATORS

Manufacturer	Griscom-Russell Co.
Type	Two-effect, submerged type, self-sealing
Capacity, lb. per hr.	11,000
Pumps	Goulds
Capacity, gal. per min.	65
Drive	Direct connected d.c. motor, 1,150 r.p.m.

BOILER-FEED PUMPS

Manufacturer	De Laval Steam Turbine Co.
Number (present)	3
Type	Centrifugal
Capacity, gal. per min.	1,200
Discharge head, total ft.	925
Drive	Two motors and one turbine

SERVICE PUMPS

Manufacturer	DeLaval Steam Turbine Co.
Number (present)	3
Type	Centrifugal
Capacity, gal. per min.	1,500
Drive	Two motors and one turbine

MISCELLANEOUS MECHANICAL EQUIPMENT

Traveling screens, vertical	Chain Belt Co.
Coal and ash handling	Two Williams crushers, Link Belt Peck carrier, Robins belt; capacity, 280 tons per hr.
Soot blowers	Diamond Power Specialty Co.
Automatic non-return valve	Schutte & Koerting Co.
Blowoff valves	Hopkinson & Co., Ltd.
Throttle valves	Schutte & Koerting Co.
Gate valves	Hopkinson & Co., Ltd.
Safety valves (Consolidated)	Bishop & Babcock Co.
CO_2 recorder	Mono Corporation
Steam-flow meters	General Electric Co.
Steam-pressure gages	Foxboro Co.
Recording thermometers	Taylor Instrument Co.
Recording pressure gages	Taylor Instrument Co.
Traveling crane, 100 ton main hook, 25 ton auxiliary hook	Shaw Electric Crane Co.

MISCELLANEOUS ELECTRICAL EQUIPMENT

Main switchboard	The Detroit Edison Co.
Motor generators, two 4,800-v., 3-ph., 60-cyle, 240-v., d.c.	General Electric Co.
Transformers	The Detroit Edison Co.

Coal Carbonization as Applied to Power-Plant Practice

Low-Temperature System of Coal Distillation—Working Temperature of Oven 1,200 Degrees —Half-Inch Layer of Coal Passed over Bath of Molten Lead—Distillation Completed in Five Minutes—Coke Obtained Suitable for Boiler Firing, Powdered Fuel or Briquetting Into Domestic Fuel

BY V. Z. CARACRISTI*

REALIZING the importance of supplementing the work completed several years ago on the development of pulverized-fuel burning means, methods and apparatus for central power stations and locomotives, and in an effort further to improve over-all furnace and boiler efficiencies, the writer associated himself with Emil Piron, a chemical physicist whose life work has been the development of high-temperature coke ovens and the commercial recovery of the by-products resulting from that method of coal distillation, and attempted the design of a low temperature system which would be free from the pitfalls which had resulted in the failure of earlier systems.

We are now able to announce the complete success of this research and development, which is a "flank attack" on some of the elements contributing to the high cost of power and gas and to the cost of smokeless fuel for domestic purposes, at the same time providing a source of supply of light oil to meet motor-fuel requirements.

The greater amount of fuel available for power plant and gas-making purposes is high volatile coal. The efficiencies obtained in the conversion of this fuel into steam and gas have reached a point where the field for improvement is practically negligible. This has been clearly realized not only by individuals but by public bodies and governments, and a vast amount of energy and money has been expended in an effort to extract from this fuel, before its destructive combustion, a number of valuable products. These efforts and their results are well known and require no amplification here. The subject of this paper is confined to those efforts which have just been completed and put on a practical commercial basis, but some of the difficulties arising in earlier failures may be of interest.

High-volatile coal contains, in gaseous form, tars and other substances which are difficult to handle when in a state of transition, and much of the difficulty met in previous attempts to handle this coal has been due to the impossibility of preventing the coal and tars from sticking to the mechanism and interrupting operation during distillation.

Another cause of difficulty has been that the gases arising from the low-temperature distillation of the coal are in extremely unstable form, and when these unstable gases come into a zone of greater heat, they break down and regroup themselves into a more stable hydrocarbon form, during which process part of the carbon molecules are liberated, attaching themselves to the various portions of the structure, building up in a manner which obstructs continuous operation.

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The problem therefore reduced itself to the creation of a structure in which the coal during the distillation process was stationary in relation to its supporting medium, and a structure in which the maximum temperature is less than that necessary to regroup the chemical elements in the gaseous atmosphere. The maximum temperature permissible is in the neighborhood of 1,300 deg. F.

Heat cannot be transferred with any degree of efficiency through any atmosphere without a large temperature head, and if the walls of the furnace are heated by external means to a degree sufficient to heat the coal in the chamber, even if in a thin layer, to a temperature necessary for the complete distillation of the complex hydrocarbon gases, the internal walls of such structure must necessarily be much higher than the 1,300 deg. maximum. The utilization of metal-to-metal contact through molten lead for the purpose of transmitting heat offered the best possible solution of the heat transfer problem.

The advantage of the application of fuel directly on a molten bath was recognized to be ideal for the purpose of heat transfer, as early as 1857, but unfortunately, after the volatile has been driven off, the coal structure becomes highly porous, and the losses of the molten material filling the pores would be so great as to make such operation prohibitive.

Modern economic conditions require continuous operation with maximum tonnage output per unit of investment cost, and belt conveyors offer the most economical method of handling material continuously.

The operation of low-temperature ovens, recovery of byproducts and the conversion of the heat into steam presuppose on the part of the power-plant executive a wide range of operating experiences which have not been heretofore required, but in a properly designed and co-ordinated plant highly specialized technical knowledge is neither necessary nor desirable in ordinary daily operation.

Many years of byproduct high-temperature coke-oven operation makes available fully developed commercial equipment and processes, under competitive conditions. A redesign of such apparatus to meet the peculiar necessities of the more unstable character of the true low-temperature product, without complicating operating features, fully covers the requirements and does not change the ideal condition of continuous and simple operation.

The superior qualities of the main product of low-temperature ovens—that is, coke—as well as other byproducts, have long been the subject of serious consideration by chemists.

Theoretically, it is evident that any coke oven or gas retort would serve the purpose, the simple expedient of reducing the temperature of the heating walls to 1,400 deg. F. being all that is required to convert either of these operations into a low-temperature distillation system. This is impracticable, however, because the thickness of the usual coal charge results in slow heat transmission and low efficiency. Such an oven would not meet commercial requirements as to volume, in order to justify the fixed charges on the investment required.

Attempts at low-temperature carbonization under these conditions were made at Barugh, England, where the compartments in the vertical heating walls of a

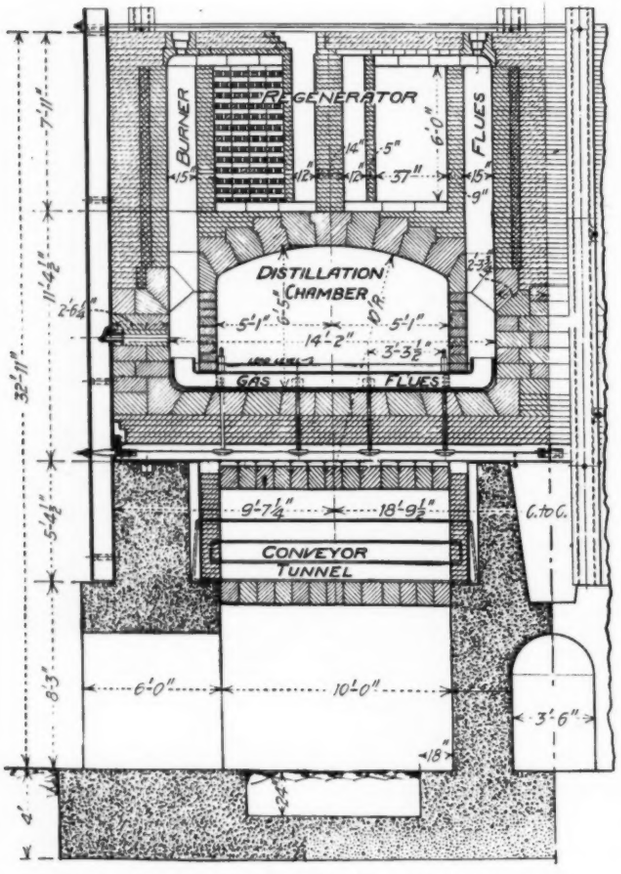


FIG. 1—SECTIONAL ELEVATION THROUGH OVEN

horizontal coke oven were constructed so that the coal charge was reduced to a thickness of 3 to 3½ in., leaving space for the free escape of the gases. In this oven, however, the coal thickness still required a time element of from seven to eight hours for distillation, the efficiency was low, and the capacity limited to about 3,000 lb. per day per oven.

It was therefore evident that some means had to be found to distill the coal at the required low temperature, at the same time permitting an output that would meet industrial conditions. This could be realized only by increasing the heat transmission from the supporting wall to the coal. To accomplish this, two methods are available: (a) To remove continuously the thin layer of coke forming along the heating walls by the distilling coal, as for example, by means of an agitator; (b) to cover the heating surface with a thin layer of coal and remove it after the coking is finished.

The former method was attempted by the International Coal Products Corporation and others. They succeeded in increasing the efficiency of their retorts. The International Coal Products Corporation succeeded in building a retort with a capacity of 20 tons of coal per 24-hour day. Their chief difficulty was in providing a satisfactory agitating device, for the reason that at the desired temperature (1,000 to 1,400 deg. F.) soft bituminous coal forms a swollen, sticky mass along the walls of the retort oven, which is almost impossible to remove except at the expenditure of great power. The problem was further complicated by the fact that at such temperature the metal of the agitating device loses much of its tensile strength.

In order to convince ourselves of the physical behavior of soft coal, especially West Virginia coal containing about 35 per cent volatile, we have made tests that indicate that the handling of such coals at temperatures between 1,000 and 1,400 deg. before complete distillation down to 15 per cent volatile must be avoided. We were therefore compelled to devise a more practical method of accomplishing the desired results by the second method open to us.

Time for Distillation Varies with Thickness of Coal Layer

Further tests showed that the rate of heat transfer increased rapidly when very thin layers of coal were used, the distillation time being reduced to a commercial basis when the thickness of the coal layer is one-half inch; also that there was no difficulty in removing the distilled product from the heated surface after the distillation had reached this point. In fact, at the end of the distillation the coke shrinks and falls freely from its supporting surface.

The products of coal distillation can be divided into two classes—primary and secondary distillation products. When coal is submitted to increasing temperatures, its more or less complicated molecules decompose progressively, and the products of decomposition distill as soon as they have reached their boiling point, giving a vapor which is a so-called primary product. If these vapors, however, before condensation, are submitted to temperatures above their distillation temperature, most of them decompose into a second class of products called secondary products. Owing to the great diversity and complex structure of these products there is no temperature limit at which the secondary products start to form. Some of the primary products decompose at relatively low temperatures, but it is generally acknowledged that the decomposition of primary products on a large scale becomes apparent only at a temperature of 750 deg. C. (1,382 deg. F.). In coke ovens and gas retorts, temperatures in the first period of distillation, where the charge is still relatively cold, correspond to so-called low-temperature distillation, while the temperatures reach to over 750 deg. C. during the second period of distillation. Therefore such distillation apparatus gives a mixture of primary and secondary products in the gas and tar.

Coke obtained at low temperatures—below 750 deg. C.—contains 10 to 15 per cent volatile matter, and when such coke is further heated it distills almost pure hydrogen. Because of the absence of heavy hydrocarbons, such coke burns readily, with practically no smoke and almost no lighting flame.

Coke of low-temperature distillation retains more nitrogen than high-temperature coke. For this reason

low-temperature distillation gives a smaller yield of ammonia, or sulphate of ammonia, per net ton of coal, as compared with the product of high-temperature distillation. The hydrogen remaining in the low-temperature coke is accounted for by the large reduction in gas volume. Another reason for such reduction in volume is that the molecules in the gas of low-temperature distillation are generally heavier than those of the gas of high-temperature origin, for the reason that they are not decomposed at the higher temperatures. The net result is that low-temperature distillation gives 6,000 to 7,000 cu.ft. of gas per net ton of coal, while high-temperature distillation gives nearly 12,000 cu.ft. At the same time the quality of the gas per cubic foot is of greater B.t.u. value than the high-temperature product. It contains less hydrogen and more hydrocarbons, and runs from 700 to 750 B.t.u. per cu.ft. as compared with 500 to 600 B.t.u. in high-temperature operation.

Low-temperature distillation, preserving the distilled products from cracking, gives a much higher yield of tar than high-temperature distillation; that is, from 10 to 20 gal. more per ton of coal treated. The percentage of very heavy bodies, that is, of pitch, which is primarily the result of cracking, is much smaller in low- than in high-temperature distillation.

The light oil derived from the tar corresponds to not less than 5 gal. per net ton of low-temperature coke. A further quantity of light oil can be extracted from the gas obtained by low-temperature distillation. This, added to the light oil from the tar, gives 10 gal. of light oil suitable for motor fuel, per ton of coal.

An oven that operates along entirely new lines has been built at Huntington, W. Va., for the low-temperature distillation of coal or any suitable material. This is a demonstration unit only, with a daily capacity of 25 tons. The first commercial realization of the research and development work carried on by the writer and his associate for the last two years in laboratory and with the test unit at Huntington, has been made possible through the initiative of Henry Ford and his organization.

The Ford Motor Co. is undertaking to build the first unit of a plant at River Rouge, Detroit, to handle ultimately 4,000 tons of raw coal a day; 1,800 tons of coke will be burned in pulverized form under boilers that are at the moment the largest operating units in existence working at high ratings with pulverized fuel, and 1,200 tons will be ground and mixed with high-volatile coal from Mr. Ford's own mines, passed through the high-temperature ovens, and the resulting metallurgical coke will be used in the manufacturing operations at River Rouge.

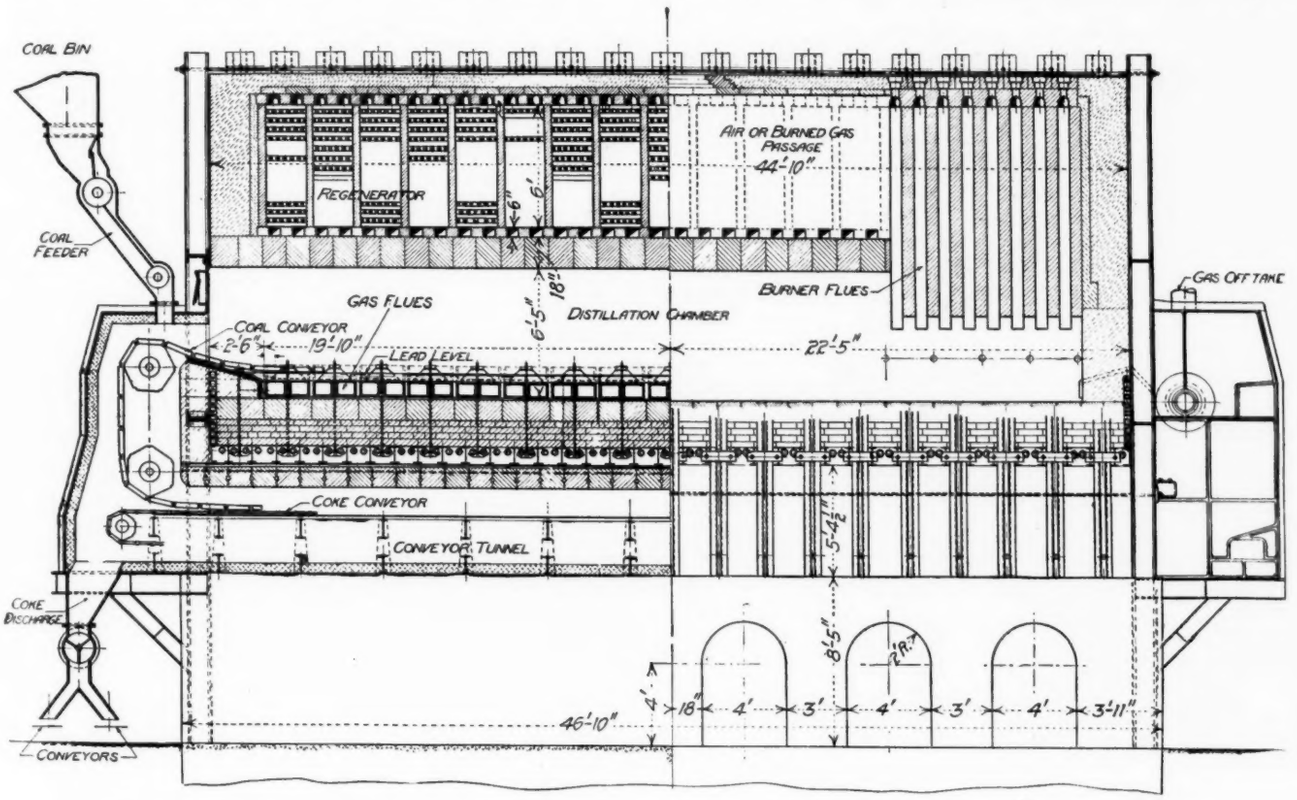


FIG. 2—LONGITUDINAL SECTION OF OVEN SHOWING COAL FEEDING AND CONVEYING ARRANGEMENT

Work is well under way on an installation for the Ford Motor Co. of Canada, Ltd., at Walkerville, Ontario, where 400 tons of coal will be handled a day, all of which will be burned in the power plant now under construction there.

The structure shown in Fig. 2 is typical of the furnaces now being put in by the Ford Motor Co. of Canada, Ltd., and by the Ford Motor Co. at its River Rouge plant, the only point of difference being that the River Rouge furnaces are 10 ft. longer than the furnaces illustrated.

The design of the commercial oven, as adopted, will consist of a clay refractory furnace 44 to 52 ft. long, having two longitudinal arched chambers 14 ft. wide and 6 ft. 5 in. total height, provided with curtain walls at each side to separate the heating and exhaust chambers from the distillation space. Cast-iron U-shaped

flues in twin form, connect the heating and exhaust chambers, the lower section of the flues being completely submerged in a bath of molten lead with refractory protection for the protruding upturned ends. These U-flues are closely placed, providing heating-gas passages spaced 14 in. apart under the entire lead surface. Any molten lead that might follow the anchor bolts holding the U-flues submerged, is chilled by the water-cooling pipes which cover the bottom and ends of the furnace. These pipes also provide a point of escape for the heat that travels up from the bottom, or return conveyor chamber. Regenerators or recuperators rest on top of the oven proper and become a permanent part of the structure.

The heat transfer and conveyor-floating medium is lead, which is ideal for the purpose on account of high specific gravity, low melting and high boiling points, freedom from affinity for extraneous elements except free oxygen, which does not exist in the gaseous atmosphere under which it works, and the fact that it is unaffected by sulphur except under temperatures several hundred degrees in excess of the maximum used.

To minimize first costs and prevent difficulties with expansion and contraction effects, the tank containing the molten lead is built of refractory brick which will not absorb lead even when made under ordinary manufacturing conditions. It is preferable, however, that

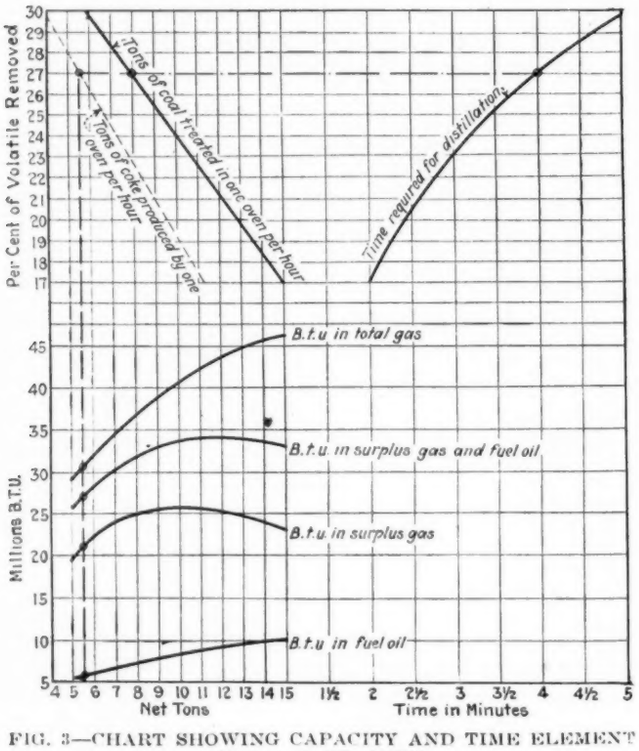

Per Cent of Volatile Removed
Tons of coal treated in one oven per hour
Tons of coke produced by one oven per hour
Time required for distillation
B.t.u. in total gas
B.t.u. in surplus gas and fuel oil
B.t.u. in surplus gas
B.t.u. in fuel oil
Millions B.T.U.
Net Tons
Time in Minutes

FIG. 3—CHART SHOWING CAPACITY AND TIME ELEMENT FOR A 40-FT. OVEN

The standard oven is 25 per cent larger, and has a correspondingly greater capacity than the oven charted.

the brick be made of finely ground clay, well compacted, dried and hard-burned.

The combustion of the heating gas is made above the surface of the molten lead, on both sides of the tank, in refractory flues where a high temperature is maintained in order to insure complete combustion. The U-shaped heating flues carry the hot combustion products through the lead bath. These flues necessitate downward combustion, as extensively employed in burning powdered coal, and in the Piron system of high-temperature coke oven. This method has proved its value. The same laws governing the equalization of heat over the furnace width apply. The cooler flues draw more gas than the hot, by reason of less obstruction to draft effect.

Each chamber is provided with a conveyor system made up of three strands of cast-iron plates, each 3 ft.

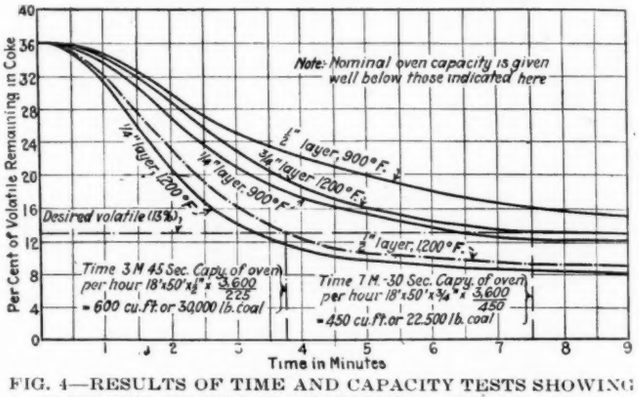

Per Cent of Volatile Remaining in Coke
Note: Nominal oven capacity is given well below those indicated here
Desired volatile (1.3%)
Time 3 M 45 Sec. Capy. of oven per hour 18"x50"x1/2" x 3,600/225 = 600 cu.ft. or 30,000 lb. coal
Time 7 M. 30 Sec. Capy. of oven per hour 18"x50"x3/4" x 3,600/450 = 450 cu.ft. or 22,500 lb. coal
Time in Minutes

FIG. 4—RESULTS OF TIME AND CAPACITY TESTS SHOWING BASIS FOR SELECTION OF WORKING TEMPERATURE AND COAL LAYER THICKNESS

wide, 18-in. pitch, held by steel hinge pins 1⅛ in. in diameter. The plates are 1 in. thick, with flanged ends, the hinges and pins being placed low enough to make a flat, unobstructed surface to receive the incoming coal. The hinge joints are so overlapped that no cracks are formed through which incoming ground coal might reach the supporting lead. These three conveyor chains operate on a common sprocket shaft of special cast iron, integral design, and are separated into strands for the purpose of simplifying manufacture. Three sprockets only are provided for the run; no appreciable energy is necessary to move the conveyor through the supporting bath, and the customary fourth sprocket is omitted, the unsupported chain acting as its own take-up.

The conveyors are supported, on their return under the furnace proper, by a series of rollers resting on rails. These rollers in turn carry a secondary conveyor system. After its passage through the heating chamber, the coal, now at a temperature of approximately 1,200 deg. F., falls on the supplementary conveyor and again passes the full length of the furnace, at half its former speed. The conveyor which has been transmitting the heat to the coal is reversed on this run, and the heat in the coal is being utilized to some extent to prevent any drop in temperature of the conveyor plates. Of greater importance, however, is the fact that this extra time in the hot gaseous atmosphere of the furnace structure frees the treated coal of the last vestige of unstable gas, but does not restrict either the time or capacity of the direct lead-heated upper portion of the structure. Accessible cast iron, gastight, and heavily heat-insulated housings carry the mechanism at both ends, and ample explosion door area is provided. All bearings are outside the heated zone and are operated without external lubrication. The power required to drive the mechanism is less than 5 hp. for each side, including the feeding device, and is therefore not more than ¾ kw.-hr. per ton output.

Waste gases leave the U-flues at temperatures slightly

above the 1,200-deg. F. temperature maintained in the bath. This heat is not lost, being used to heat the incoming air, either by recuperators of special design or by ordinary regenerators, as shown in Fig. 1.

There are still a number of commercially unsolved problems in this development. The laboratory and practical research work done, however, indicates that no serious difficulty will arise in the commercial recovery of the byproducts, which, in simple commercial form, will consist of the following, per ton of coal handled: (1) 8,000 to 7,000 cu.ft. of 600-700 B.t.u. gas; (2) 5 gal. motor fuel directly stripped from the gas; (3) ammonia in an amount corresponding to 20 lb. of sulphate of ammonia stripped from the gas and condensation liquor; (4) 25 to 30 gal. of a crude oil-like character of very light tar, as main condensation product and the recovery from the tars of the following: (1) 5 gal. motor fuel; (2) 2½ to 3½ gal. creosote oil; (3) 1½ to 2½ gal. lubricating oils and (4) 8 to 12 lb. of lubricating grease. This will leave a residue of heavy oil of tar-like character, which will be suitable for use as fuel oil.

Primarily, the object is to obtain a material of coke-like character, high in carbon, containing not more than 15 per cent volatile, in the form of stable hydrocarbon, that will burn without smoke and will be suitable for any of the following purposes: (1) To be briquetted into a smokeless domestic fuel of anthracite character; (2) to be pulverized and burned directly in furnaces; (3) to be burned directly on chain-grate stokers; (4) to be ground and mixed with high-volatile coal for the purpose of making metallurgical coke.

Special Feeding Equipment Necessary

One of the problems requiring special consideration was the feeders, of which there are two for each oven, each of which has to deliver a stream of coal 9 ft. wide in a controllable thickness and at variable speeds. Ordinary methods of feeding were not applicable, owing to the temperature at the receiving point, and the feeders had to be located a sufficient distance from the furnace housing to provide working room around the apparatus.

The cycle of operation is continuous. The coal is fed from bunkers in a stream approximately one-half inch thick and at a rate corresponding to the speed of the distillation plate. It is "eased" on these plates by a secondary feeding roll to prevent "splashing" of particles or the formation of dust. These plates, when receiving the coal, are near their maximum temperature, and distillation starts immediately. When the plates reach the metal bath after receiving their charge of coal (in about 30 seconds), they quickly regain the heat absorbed by the coal and continue to transmit heat, now derived direct from the metal bath, to the coal layer resting on their surface. This heat is further augmented by the radiation from the surrounding refractory walls, and the resistance of the half-inch layer of coal to heat infiltration is quickly overcome.

A relatively hard and non-sticky film of devolatilized coal forms next to the plate almost instantly, and even if the speed of the conveyor is such that the coal is not thoroughly "cooked" in its passage over the direct-contact heat zone, it will not adhere to the smooth surface of the plates. The coal particles which originally are crushed so as to pass a ½-in. screen become welded into a continuous, devolatilized sheet of honeycomb-like structure, still slightly plastic (due to heat influences), and the sheet leaves this first run at the full maximum furnace temperature. The overhanging portions of this coke sheet break off by their own weight, and fall on the surface of the return conveyor, and together with the plates, now reversed, pass back under the heat-transmitting chamber. This extra time gives further opportunity for the escape of the small quantity of gas remaining, which gas serves the very useful purpose of keeping oxygen from the lower part of the structure, not only preventing local oxidation of the gases themselves, but preserving the metal conveyor parts. After completing the return passage, the coke falls into a hopper and passes through a star feed device onto the coke-collecting conveyor. Coke leaving this furnace and coming into immediate contact with air will not flash, and unless immediately piled, no water-quenching is necessary. The coke can be immediately crushed and transferred to bunkers for use in the forms previously noted.

The same uninterrupted cycle of continuous operation will follow the gas arising from the distillation process. Exhausters create a suction in the collecting mains. Automatically operated "butterfly" valves allow the escape from the oven of only sufficient gas to maintain pressure enough to prevent the infiltration of air. Automatic admission of low-pressure steam vapors supply any deficiencies that might occur during periods when the process is being started or stopped, and the gases from the coal are not in sufficient volume to maintain the desired plus pressure (about 2 mm. of water). The gases first pass through coolers which condense the oils which flow by gravity to storage and settling basins, and then from the pressure side of the exhausters to ammonia scrubbers, where water picks up the ammonia. Leaving the ammonia scrubbers, the gas passes through oil columns and thence to the gas holder or point of ultimate consumption.

Careful observation of the heat necessary for devolatilization at the Huntington Plant indicates that the following heat balance will approximate the operating requirements for coal having 36 per cent volatile and 5 per cent moisture, on a pound basis:

	B.t.u.
Heat necessary to raise moisture from 72 to 212 deg.	7.0
Latent heat of steam	48.5
Note: The latent heat necessary to distill the water of composition is not taken into account, because this water comes from internal combustion with the oxygen of the coal and the heat generated is sufficient for the distillation of the resulting water.	
Heat necessary to raise the temperature of the steam to its exhaust temperature of 800 deg.	19.7
Heat necessary to distill the hydrocarbons and raise their temperature from 72 deg. to the exhaust temperature of 800 deg.	91.0
Heat necessary to raise the coke from 72 deg. to temperature at which it leaves the oven (1,000 deg.)	181.8
Total B.t.u. required for distillation	348.0
Heat necessary for radiation, in the Huntington oven	180.0
Total heat requirements, B.t.u.	528.0

Proper insulation will reduce the radiation losses to not more than 100 B.t.u., making the total heat input necessary for each pound of coal treated, 428 B.t.u. The efficiency of the apparatus as a heat-transfer medium will be at least 80 per cent, so that the total heat input per pound of coal treated will be 560 B.t.u., or 1,120,000 B.t.u. per ton of coal treated. Assuming that this coal has 13,000 B.t.u. as received, or 26,000,000 B.t.u. per ton, the heat losses will be 4.3 per cent, and the thermal efficiency of the process will be 95.7. In view of the ordinary daily operation in high-temperature plants, where a heat efficiency of 92 per cent is not unusual, this figure will balance relatively correct with accepted data.

The basic differences between low-temperature dis-

tillation according to the process herein described, and those which are well known, lie in the following: (1) The use of a moving, continuous platform, carrying a thin layer of coal and passing through a heat-transmitting chamber; (2) the use of a molten material for transmitting the heat by metal-to-metal contact with the conveyor; (3) the use of a molten material for treating the conveyor through the distillation chamber; (4) means for providing heat to the bath through flues located within the bath.

At present there is no commercial advantage in distilling at low temperatures such coals as give metallurgical coke, because of the great value of such coke. Low-temperature distillation can be most advantageously applied, however, to coals and lignites that do not yield good metallurgical coke and will at the same time provide a material which can be mixed with coal containing the resins necessary for agglomeration into coke, in proportion to the amount of such resins available, the resulting product being a metallurgical coke of high quality.

COST OF OPERATION DISTRIBUTED ON WEIGHT BASIS—CHARGES OTHER THAN COAL (NET TON OF 36 PER CENT VOLATILE COAL) ON HOT GAS PRODUCERS FOR HEAT SUPPLY.

Product Charged	Oven Operation	Producer Operation	Miscellaneous Expense	Fixed Charges	Manufacturing	Total
*1. Coke, 1,340 lb.	$0.150	$0.180	$0.075	$0.3375	.....	$0.7425
2. Gas, 7,000 cu.ft.	.026	.0312	.013	.0525	.....	.1287
3. Tar, 25 gal.	.02	.024	.01	.045	.....	.099
4. Ammonia, 5 lb.	.0005	.0006	.00025	.00112	.38	.3824
5. Light oil (gas), 5 gal.	.0035	.0042	.00175	.00787	.30	.3173
6. Total	$0.20	$0.24	$0.10	$0.45	$0.68	$1.669
7. Total without tar	.18	.216	.09	.405	.68	1.57
8. Light oil (tar), 5 gal.	$0.007	$0.0084	$0.0035	$0.03325	$0.14	$0.1921
9. Creosote oil, 3 gal.	.005	.006	.0025	.92375	.10	.1372
10. Fuel oil, 10 gal.	.008	.0096	.0040	.038	.16	.2196
11. Total	$0.02	$0.024	$0.01	$0.095	$0.40	$0.548
12. Grand total (items 7 and 11)	$0.20	$0.24	$0.10	$0.50	$01.08	$02.119

*After deducting 160 lb. used in hot gas producer.

The economic justification for low-temperature plants is found in any one or a combination of the following:

1. At the mines, where high-volatile coal or lignite can be marketed as smokeless briquettes, motor fuels, lubricants, creosote, fertilizers, and gas and fuel oil.

2. Between the mines and principal point of ultimate consumption where a market can be found for gas, and where a "milling in transit" rate will work out to advantage when considered in terms of all the resulting freight combinations on byproduct tonnage.

3. In large central-power-station operations (more than 40,000 kw.) whose available coal contains more than 26 per cent volatile.

4. In large domestic gas plants, where a combination of low-temperature operations supplemented by the destructive distillation of the resulting coke will work out very attractively.

5. In large manufacturing operations requiring a combination of power and gas or fuel oil in volume sufficient to use 400 tons or more of coal a day.

6. Under unusual conditions of fuel scarcity.

7. In the conversion of natural resources into fuel oil, for the conservation of domestic capital that might otherwise be expended abroad for material derived from available coals and lignites.

8. In railroad operations, where the coke can be used either alone, in powdered form or combined with the fuel-oil residue, for the operation of locomotives, when fuel requirements are usually sufficient to justify the capital expenditure necessary.

9. In oil-bearing shale-rock operations, where the material can be cheaply quarried and prepared to sizes of one-half inch and under, and where the 5 per cent heat loss, fixed charges and operating expense will not outweigh the cost of natural petroleum available in the territory.

10. In the distillation of sawdust and other wood residue, for the purpose of recovering the wood alcohol, acetic acid and pitch contents, and the conversion of the residue into charcoal.

SUMMARY

Low-temperature distillation of coal must be made at temperatures between 800 and 1,300 deg. F., which constitute the extreme limits.

A temperature must be chosen that will give large amounts of tar and oils, low percentage of volatile matter in the coke and a large production in the oven. This temperature must be combined with the most convenient thickness of coal layer in order to insure speed of heat transfer and production.

The distillation process cannot be economically carried beyond a point where the volatile matter is reduced below 10 per cent.

After the volatile matter has been reduced to 15 per cent, the coke loses its sticky appearance and the distilling gases lose their smokiness. The coal will then burn without evidence of smoke.

About 1,200 deg. working temperature is most suitable to meet heat-transfer and production-capacity requirements.

The oven distills a thin layer of coal spread on a continuous belt conveyor so as to increase the speed of the heat transmission through the coal and the output of the oven, without the necessity for removing the coal during distillation.

Another feature of the oven is to float the conveyor on a bath of molten lead, maintained at the desired temperature (1,100 to 1,200 deg. F., but in any case not above 1,300 deg. F. which is the maximum temperature for producing coal distillation of primary nature) so as to insure the rapid transmission of heat to the coal without the use of high-temperature radiating walls. In the gaseous atmosphere no lead losses will occur through oxidation, and no change in the load will occur through the effect of the sulphur which exists in this atmosphere. The molten lead has been found a most valuable metal for the purpose, on account of its floating power and heat-transmitting qualities. Means have been provided to hold the molten lead at the desired temperature in a tank of refractory masonry, and to carry to the lead, by U-shaped flues, an amount of heat sufficient for distillation.

Under these conditions it has been found that commercial results are obtained with a coal layer one-half inch thick which distills completely into low-temperature coke (10 to 12 per cent volatile) in less than five minutes, and more rapidly when a higher percentage of volatile is desired in the resulting coke.

The low-temperature coke obtained from this process has all the qualities of low-temperature coke as produced under laboratory conditions, and constitutes a most desirable smokeless fuel for improving the coking qualities of high-volatile coal for use in steam boilers on stokers, as powdered fuel, or for briquetting into domestic fuel.

Some Pulverized-Fuel Installations in Power Plants

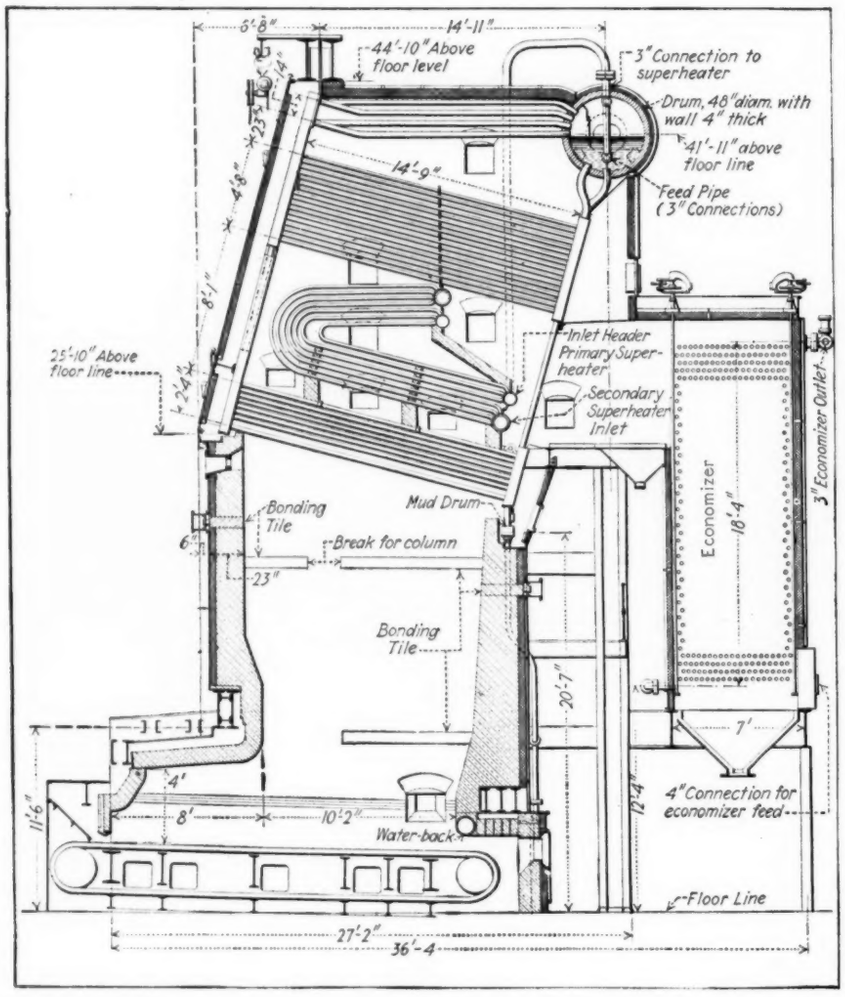
Owner	Plant	Boilers	Mills	Drier	Method of Conveying	Burners	Water Screen	Furnace
*Milwaukee Electric Railway & Light Co., Milwaukee, Wis.	Oneida St	5—4,680 sq.ft. Edge Moor	Raymond	Wood to replace Ruggles-Cole	Screw	Lopulco	Lopulco	Solid wall
*Milwaukee Electric Railway & Light Co., Milwaukee, Wis.	Lakeside	8—1,308 sq.ft. Edge Moor	Fuller	Fuller Rotary	Fuller Kinyon Pump	Lopulco	Lopulco	Solid wall
*Allegheny Steel Co., Brackenridge, Pa.	Brackenridge	7—3,330 sq.ft. Wickes 1—4,000 sq.ft. Erie City.	Raymond	None	Screw	Lopulco	None	Solid wall
*Morris & Co., Oklahoma City, Okla.	Oklahoma	5—5,000 sq.ft. 2—3,000 sq.ft. Edge Moor	Raymond	Ruggles-Cole	Screw	Lopulco	None	Solid wall
*Ford Motor Co., Detroit, Mich. (Installation now being duplicated)	River Rouge	4—26,470 sq.ft. Ladd	Raymond	None	Screw Conveyor	Lopulco also Lopulco gas burners	None	Solid wall
*St. Joseph Lead Co., Bonne Terre, Mo.	River Mines	2—768 sq.ft. Stirling	Raymond	Ruggles-Cole	Screw Conveyor	Lopulco	None	Solid wall
*U. S. Coke & Coal Co., Gary, W. Va.	Gary	2—8,000 sq.ft. H.W.T.	Fuller Screen Type	Fuller Rotary	Fuller Kinyon Pump	Fuller	None	Solid wall
*Lima Locomotive Co., Lima, Ohio	Lima	6—4,000 sq.ft. Wickes 1—5,000 sq.ft. Heine	Raymond	Ruggles-Cole	Screw	Lopulco	None	Solid wall
*Duquesne Light Co., Pittsburgh, Pa.	Brunots Island	1—8,220 sq.ft. Stirling	Raymond	None	Screw	Lopulco	Lopulco	Hollow wall
*West Penn Power Co., Pittsburgh, Pa.	Springdale	1—15,320 sq.ft B. & W.	Raymond	None	Screw	Lopulco	Lopulco	Hollow wall
*Pennsylvania Salt Co., Wyandotte, Mich.	Wayndotte Michigan	1—8,220 sq.ft. Stirling	Raymond	None	Screw	Lopulco	Lopulco	Holow wall
‡Union Electric Co., East St. Louis, Mo.	Cahokia Station	8—17,800 sq.ft. B. & W.	Raymond	Wood	Quigley Air System	Lopulco	Lopulco	Hollow wall
Norfolk & Western R.R., Roanoke, Va.	Roanoke	6—2,000 sq.ft. 2—6,000 sq.ft. B. & W.	Fuller Screen Type	Fuller Rotary	Fuller Kinyon Pump	Fuller	None	Solid wall
*St. Joseph Lead Co., Bonne Terre, Mo.	River Mines	2—7,680 sq.ft. Stirling	Raymond	Ruggles-Cole	Screw	Lopulco	Lopulco	Hollow wall
†United Electric Railways Co., Providence, R. I.	Providence	3—12,600 sq.ft. Bigelow & Hornsby	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall
†Rochester Gas & Electric Corp., Rochester, N. Y.	Rochester	2—8,750 sq.ft. Bigelow & Hornsby	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall
‡Clark Thread Co., Newark, N. J.	Newark	10—5,000 sq.ft. Stirling	Fuller Screen Type	Fuller Rotary	Fuller Kinyon Pump	Fuller	None	Solid wall
‡Kobe Municipality, Kobe, Japan	Kobe	1—5,500 sq.ft. B. & W.	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall
*Eline's Incorporated	Milwaukee	4—5,000 sq.ft, Wickes	Fuller Lehigh	Fuller Lehigh	Screw	Fuller Lehigh		Hollow wall
‡Firestone Tire & Rubber Co., Akron, Ohio	Akron	3—6,000 sq.ft. Stirling	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall
Mathieson Alkali Co., Saltville, Va.	Saltville	2—5,000 sq.ft. Wickes 4—2,500 sq.ft. Cahall 4—2,500 sq.ft. Wickes	Fuller Screen Type	Fuller Rotary	Fuller Kinyon Pump	Fuller	None	Solid wall
Wheeling Steel Corp., Wheeling, W. Va.	Whitaker	1—8,290 sq.ft. Connelly	Aero	None	Aero Air System	Aero		Hollow wall
‡Ford Motor Co. of Canada, Ltd., Ford, Ontario	Ford, Ontario	3—13,500 sq.ft. McAllenan	Raymond	None	Screw	Lopulco	Lopulco	Hollow wall
‡Toho Electric Co., Japan	Japan	1—8,000 sq.ft. B. & W.	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall
‡St. Joseph Lead Co., Bonne Terre, Mo.	River Mines	1—15,000 sq.ft. Heine	Raymond	Ruggles-Cole	Screw	Lopulco	Lopulco	Hollow wall
‡Nippon Electric Co., Japan	Japan	4—10,800 sq.ft. B. & W.	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall
‡Cleveland Electric Illuminating Co., Cleveland, Ohio	Lakeside	4—30,600 sq.ft. Stirling	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall
‡Milwaukee Electric Railway & Light Co., Milwaukee, Wis.	Lakeside	8—17,500 sq.ft. Edge Moor	Fuller	Fuller Rotary	Fuller Kinyon Pump	Lopulco	Lopulco	Hollow wall
‡Farr Alpaca Co., Springfield, Mass.	Holyoke	3—10,000 sq.ft. Wickes CD	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall
‡St. Paul Gas Light Co., St. Paul, Minn.	St. Paul	3—10,000 sq.ft. Heine	Raymond	Wood	Screw	Lopulco	Lopulco	Hollow wall

Note: Other stations where pulverized coal has recently been decided upon but not yet installed, are under 5 boilers at Colfax; 3 boilers at the Middletown, Pa., plant, Metropolitan Edison Co.; and 4 boilers at the Valmont, Colo., plant, Denver Gas & Electric Co.

*Operating. †Being installed. ‡Not yet installed.

Calumet Station To Have 1,200-Lb. Boiler

AS ANOTHER step in the progress toward the use of higher steam pressures, it is interesting to learn that about the first of the year the Commonwealth Edison Company, of Chicago, ordered one boiler designed for an operating pressure of 1,200 lb. per sq.in. It will be an experimental installation, and the intention is to use this boiler at the Calumet Station and to put in with it a small "extra-high-pressure" turbine taking steam from the boiler at 1,200 lb. pressure and exhausting at 300 lb. pressure into the steam mains which supply the large turbines of the station. The turbine has not yet been ordered and the details of the system have not been completely worked out. The details of the boiler design, however, have been practically completed by the Babcock & Wilcox Co. in conjunction with the consulting engineers of the Commonwealth Edison Company.



SECTION THROUGH BOILER, SHOWING SECONDARY SUPERHEATER AND FOUR-INCH THICK DRUM

The unit is of the inclined-header, cross-drum type and comprises a lower deck of eight-high sections of 2-in. tubes having a setting height of 25 ft. 9¾ in., a primary and a secondary superheater in an interdeck space 8 ft. 1¼ in. between decks, an upper deck of seventeen-high sections of 2-in. tubes, horizontal 3¼-in. circulating tubes entering a 48-in. cross-drum, and a Babcock & Wilcox steel contraflow economizer. The lower deck is not baffled; the upper deck has a vertical baffle, causing the gases to make two passes. The complete unit is about 28 ft. wide, 36½ ft. deep, including the economizer, and 45 ft. high above the floor. The heating surfaces have not yet been definitely fixed, but they will be approximately as follows: Boiler, 15,750 sq.ft.; primary superheater, 2,120 sq.ft.; secondary superheater, 3,300 sq.ft.; economizer, 9,230 square feet.

The headers have 1¼-in. thickness front and back and ⅝-in. sides, and are designed to give the tubes a stagger of nearly 4 in. The eight tubes in each section of the lower deck are expanded into nine-high headers, the tube space not filled being that next to the bottom. The arrangement of headers and nipples connecting them is the same as in the Waukegan boiler described in the Sept. 12, 1922, issue. The mud drum is 7¼ in. square, 1 in. thick and extends through each side of the setting, with a flange for blow-off valves at each end.

The cross-drum is a forged steel cylinder 48 in. in diameter and 4 in. thick, with integral drum heads, each with a manhole closed by a 12 x 16-in. manhole fitting. In order that the holes for connecting the circulating tubes to the drum may leave the largest practicable ligaments between circumferential rows of holes, an unusual arrangement of connections has been adopted. At the top of each uptake header two horizontal circulators are connected, but the circulators from each alternate header are bent downward and sidewise so that they are connected to the drum in the same circumferential row as the circulators without such bends. This makes the distance between these circumferential rows about 16 in.

In the same way, the downtake nipples are not straight, but bent so that two downtake headers are connected to each of these circumferential rows.

The drum has four 3-in. nozzles for safety valves, a 3-in. nozzle for the saturated-steam connection to the primary superheater, and two 3-in. feed-water connections.

The primary superheater has 8-in. headers drilled for three staggered rows of tube holes, with 72 tubes in each row. It is designed to raise the temperature of the steam under 1,200 lb. pressure to 750 deg. The secondary superheater has 11¾-in. headers drilled for four staggered rows of 72 tubes each. This secondary superheater incloses the primary superheater and is intended to raise the temperature of the exhaust from the extra-high-pressure turbine to 750 degrees.

The economizer has 44 rows of tubes with twenty 2-in. tubes 20 ft. long in each row.

Reaction Turbine Uses Axial Clearance in High-Pressure Blading

New Features Incorporated in the Design of the 5,000-Kw. Turbines Installed in the Municipal Plant of Ashtabula, Ohio

TWO 5,000-kw. 3,600-r.p.m. turbo-generators, which deliver three-phase 60-cycle current at 2,300 volts, have recently been built by the Allis-Chalmers Manufacturing Company for the municipal plant at Ashtabula, Ohio. These are the first two units of the new design that have been installed. Although a casual reference to Fig. 1, an exterior view of the unit, and to Fig. 5, a longitudinal section, may not show any radical departure from the previous design, nevertheless the turbine contains a number of improved features.

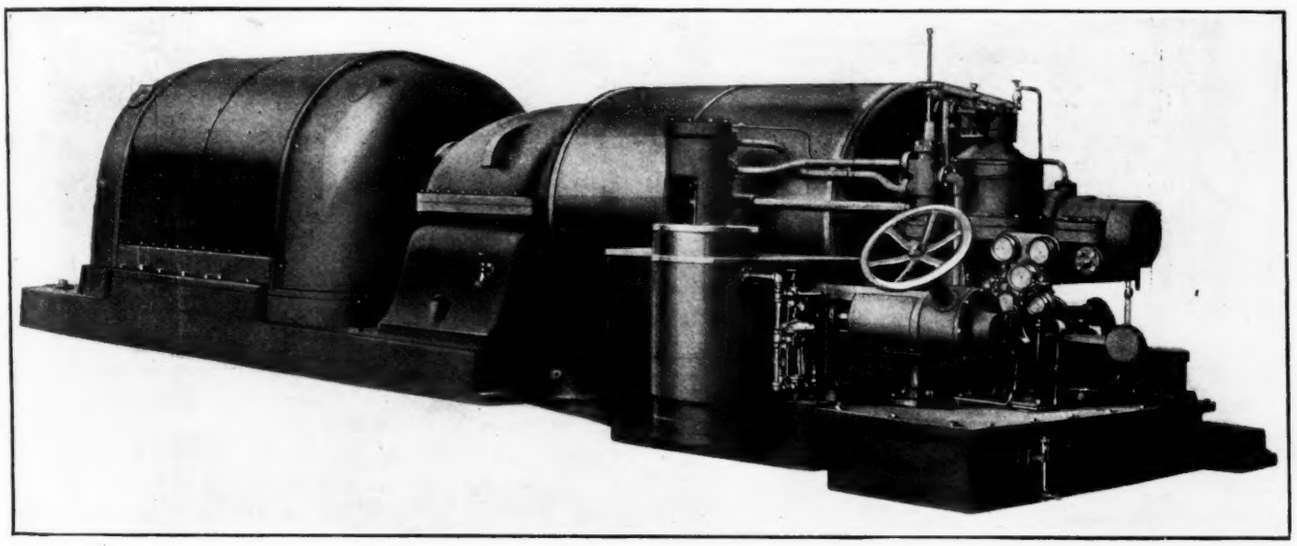


FIG. 1—ONE OF THE 5,000-KW. ASHTABULA TURBINES

One of these improvements is a new method of baffling to reduce the leakage of steam around the ends of the blades. In the old construction the shroud ring came in close proximity to the cylinder and spindle walls, giving as close radial clearance as was possible while making allowance for vibration, whipping of the turbine shaft and the slight distortion of the turbine cylinder that may take place under high temperatures. As indicated in Fig. 5, the new construction has large radial clearance but small axial clearance. This is obtained by casting a projection on the blade foundation ring, machining it and bringing the lip of the shroud ring into close proximity in the axial direction. By changing the shape of the blade shroud ring in this way, the radial clearances are large and excessive steam leakage is prevented by the axial baffles formed by bending over the lip of the shroud ring. As the axial clearance is not affected by vibration, whipping of the shaft or distortion of the turbine cylinder, the clearance can be reduced to one-third or one-fourth of the usual radial clearance. This construction naturally reduces steam leakage around the blades and permits the clearance to be adjusted as desired by movement of the spindle endwise. With the end shroud ring or radial clearance no adjustment is possible.

As indicated in the sectional view of the turbine, Fig. 5, a number of forged steel rings carrying only one or two rows of blades replace the usual drum construction. This semi-ring construction, which is applied only to the lower stages, permits the use of carbon steel in preference to alloyed steel. The larger blading on the spindle at the low-pressure end is made of Monel metal, as for blading subjected to high stress it is considered by the builder superior to the copper-nickel used previously. Apart from the material no change has been made in the construction of the blading.

Another improvement, made with a view toward better economy, is the elimination of the third or low-pressure balance piston. Instead of allowing the steam leakage over the balance piston to go directly to the condenser as in the older design, any steam leaking over the balance piston at the high-pressure end is conducted through equalizing pipes to the beginning of the third stage in the cylinder, in which it must do useful work before being discharged to the condenser. To counteract the overbalancing of the turbine spindle axially toward the exhaust end by the elimination of the third balance piston, a thrust bearing of the Kingsbury type has been provided.

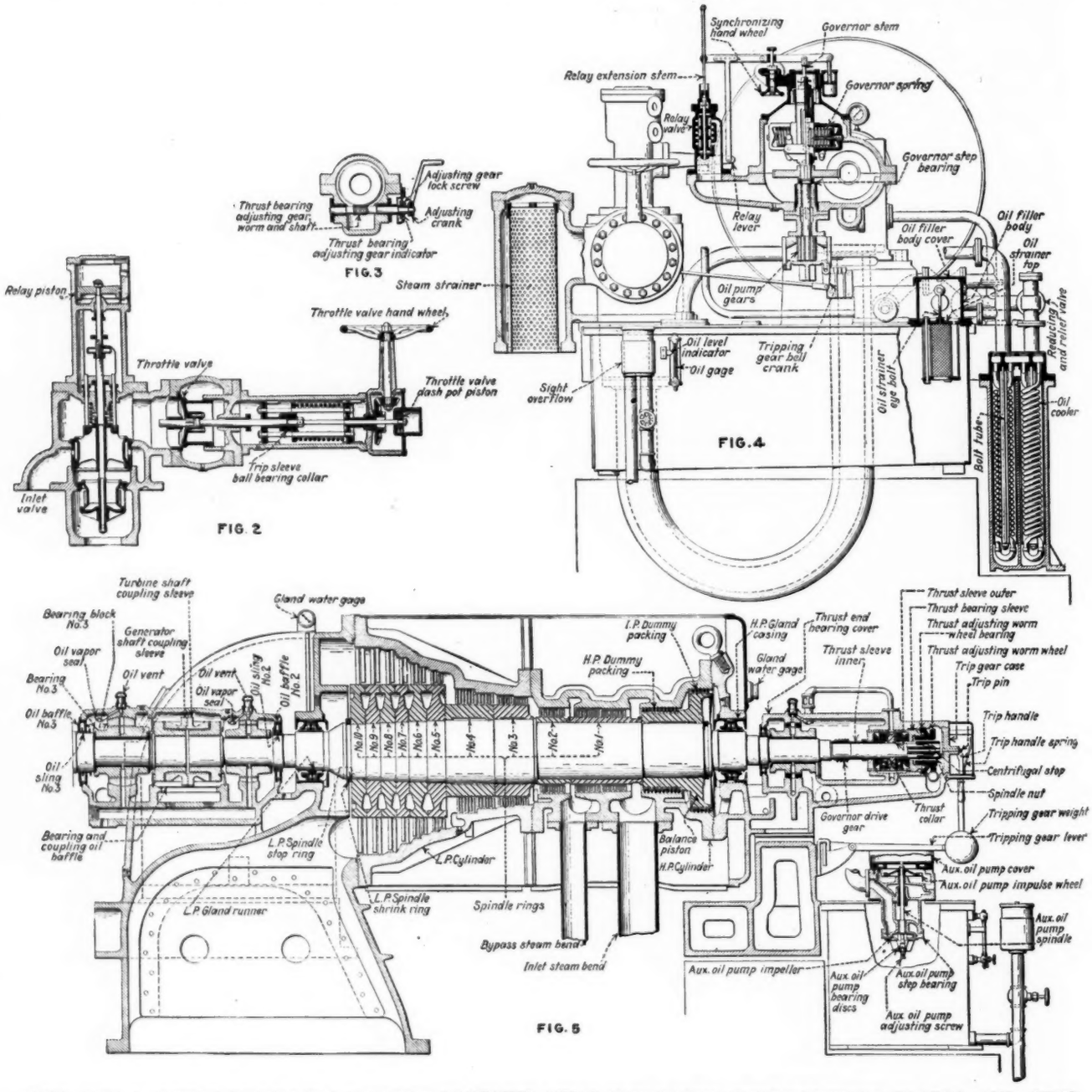
To insure rigid cylinder construction, the exhaust end, including the bearings, is supported on feet cast on and located symmetrically on the center line of the exhaust nozzle. With this arrangement it is possible to eliminate the expansion joint and bolt a spring-supported condenser directly to the exhaust nozzle.

In these machines and all smaller units the throttle valve, inlet valve and bypass valve are all included in

the steam chest, Fig. 2. The inlet and bypass valves are operated by an oil relay cylinder, and the throttle valve is of the quick-closing trip type similar to the standard design. In the old construction the bypass valve was placed on the cylinder of the machine. No change has been made in the governor regulation.

A new feature, however, is the provision of a separate oil tank of capacity approximately double that of the one provided on the same sized machine of older design. Under less rapid circulation, made possible by this additional storage capacity, the oil has more time to come to rest in the tank and free itself from air. Larger storage capacity is in line with present tendencies, as engineers generally have come to the conclusion that the tank in the turbine base is not large enough to permit maintaining the oil in the best condition. In this connection another improvement is the provision of an oil cooler of new design, Fig. 4, in which the water circulates through the tubes and the oil around the tubes. With the new cooler it is said that satisfactory oil temperatures can be maintained with the use of considerably less cooling water.

At the plant these units are operating under a steam pressure of 190 lb. gage at the turbine throttle, 125 deg. F. superheat, and 28 in. of vacuum. Under these steam conditions they were tested out in the shop with



FIGS. 2 TO 5—ROTOR OF 5,000-KW. TURBINE CONTAINS AXIAL-CLEARANCE HIGH-PRESSURE BLADES AND SEMI-DISK CONSTRUCTION IN THE LOW-PRESSURE AREA

Fig. 2—Hand throttle emergency valve, main steam throttling valve and hydraulic cylinder may be removed as one unit. Fig. 3—Hand adjustment lever moves Kingsbury thrust bearing. An indicator shows relative axial position of the shaft. Fig. 4—Oil cooler at the right circulates oil inside of tubes. The oil tank is about twice the usual capacity. Fig. 5—Two dummy pistons and a Kingsbury thrust bearing replace the three balance pistons formerly used. Oil is supplied from a pump geared to the turbine shaft with an auxiliary-driven pump located as shown at the lower right.

the results shown in the accompanying table. It will be noticed that at all loads the guaranteed water rates have been bettered. At the full load of 5,000 kw. a

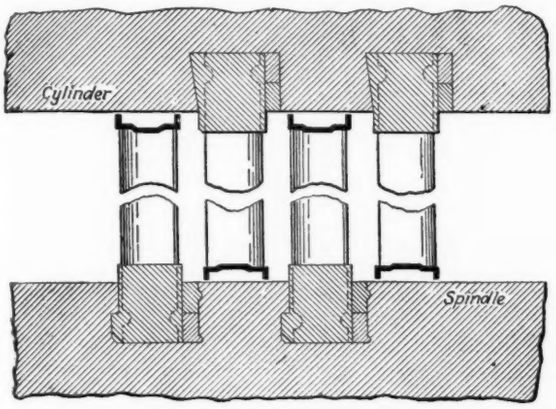


FIG. 7—LARGE RADIAL AND SMALL AXIAL CLEARANCE

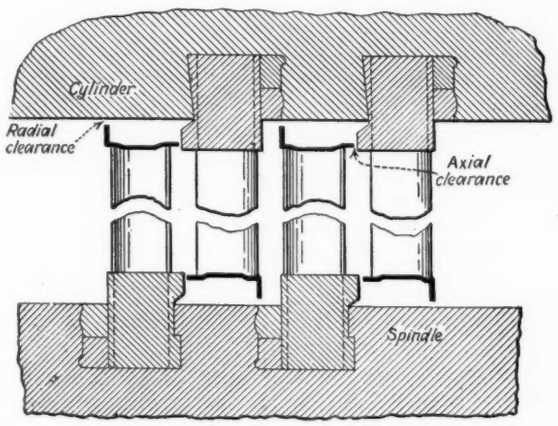


FIG. 6—INDICATING RADIAL CLEARANCE OF FORMER CONSTRUCTION

water rate of 13.07 lb. per kw.-hr. is 0.73 lb. below the guaranteed figure of 13.8.

GUARANTEED STEAM CONSUMPTION EXCEEDED

Kw. Load, 80 per Cent P. F.	Guaranteed, Lb. per Kw.-Hr.	Obtained, Lb. per Kw.-Hr.
1,250	18.1	17.70
2,500	14.85	14.57
3,750	13.9	13.57
5,000	13.8	13.07

Following two years of careful research work by the engineers of the Southern California Edison Co. and approximately one year's work on the reconstruction of the Big Creek transmission lines for operation at 220,000 volts, these lines were put in operation on May 5, 6, 12 and 13 of this year. The conversion of the Big Creek lines from 150,000 to 220,000 volts was brought about by the necessity for additional transmission capacity between the Big Creek power development and Los Angeles. After comparing the cost of constructing a duplicate set of 150,000-volt lines with rebuilding the existing lines for 220,000 volts, it appeared that about seven million dollars could be saved by reconstructing the existing lines for the higher voltage. While electrical manufacturers were willing to construct transformers and switches to operate at 220,000 volts, a transmission line for that voltage had never been built before, and it remained for the engineers of the Southern California Edison Co. to design a line and method of insulating this voltage.

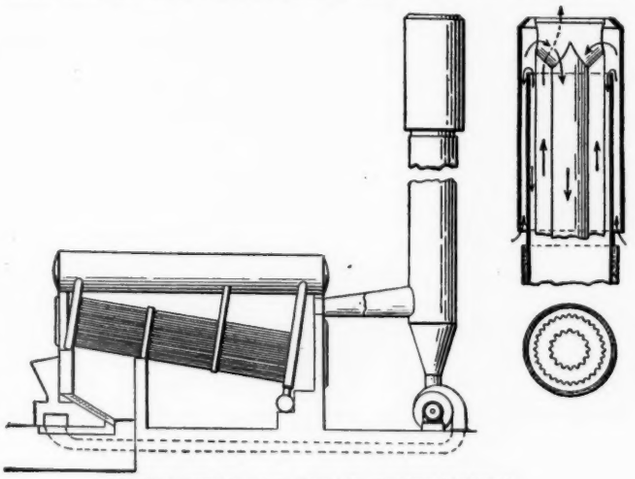
Preheating Combustion Air with Stack Gases

A device intended to increase the thermal efficiency of boilers, forges, heat-treating furnaces, kilns, etc., by transferring to the air required for combustion, much of the heat ordinarily wasted, has been designed and patented by R. Schlemm, of 528 Wrightwood Ave., Chicago.

The new heat exchanger is called a recuperator. As shown in the accompanying drawings, it is incorporated in the stack. With but slight increase of the thickness of the plates, self-supporting steel stacks of present approved types are suitable to conversion. Spaced concentrically within the outer supporting stack are two smaller stacks, one within the other, built of thin corrugated metal, forming three flues, the outer and central flues being air ducts and the intermediate flue carrying the waste gas in a direction opposite to the air currents.

This arrangement of stacks follows the counterflow principle and, what is more important, the countercurrents are parallel, with the result that the heat from the gases is compelled to flow radially to the adjacent air by a uniform thermal head at all sections of the recuperator. This is most important because the rate of heat transmission per square foot will be uniform and an average maximum, at the cool end as well as the hot end of the stack, thereby tending to reduce to a minimum the amount of heat-transfer area required for a predetermined efficiency.

In boiler practice the upper end of the stack is hooked to prevent contamination of the incoming air by admixture of waste gas, and in the case of a battery of metal furnaces a pressure main running near the upper vents, takes care of the proper air supply. In general, for low-temperature work (about 800 deg. F.) the outer stack should be covered with asbestos for three-fourths



NEW TYPE OF HEAT EXCHANGER

of its length from the bottom, while for the higher temperatures (up to about 1,600 deg. F.) a thin refractory lining on the inside of the outer shell is advisable and the intermediate stacks should be made of calorized steel for about one-fourth the height from the bottom. In the case of liquid or gaseous fuel, the preheated air should mix with the fuel at a point beyond the nozzle to prevent carbonizing, so that present burner equipment designed along approved lines will meet the requirements.

The Benson Super-Pressure Plant—Its Scientific Basis

By P. W. SWAIN*

FOR general information regarding the Benson super-pressure plant, the reader is referred to the article on page 796 of the May 22 issue. The main purpose of the present article is to make a study of the Mollier and temperature-entropy diagrams as a basis for estimating the relative thermal efficiencies obtainable with various methods of operating high-pressure plants, and particularly under the conditions possible with the Benson plant. Before this scientific side of the question is taken up, the main features and present status of the Benson plant will be briefly reviewed.

The patents of M. Benson (held by the Benson Engineering Co., Ltd., of London) cover a wide variety of possible methods of operation. Their common basic feature is the generation of vapor from water, mercury or any other liquid by subjecting the liquid to a pressure somewhat above its critical pressure and gradually raising the temperature up through the critical temperature.

THE generation of steam at the critical point (3,200 lb. pressure and 706 deg. F. temperature) is the essential feature of the Benson super-pressure plant, a general description of which appeared in the May 22 issue. The present article aims to inquire somewhat more thoroughly into the scientific principles underlying this and other systems for the production and utilization of high-pressure, high-temperature steam. The Mollier and temperature-entropy diagrams are used in investigating the possibilities of various methods of operation.

As in the previous article, the Marks and Davis steam table figures of 3,200 lb.[1] and 706 deg. F. will be taken as the pressure and temperature of water at the critical point. Assuming the correctness of these constants, the Benson steam generator must operate under a pressure somewhat in excess of 3,200 lb., so that "evaporation" may take place at 706 deg. without boiling or change of specific volume or total heat. Thereafter the steam may be superheated, throttled, resuperheated, expanded adiabatically, etc., in any desired manner. It is fundamental with the Benson System that the steam be generated at the critical point even where it must be throttled to a lower pressure before using. Thermally, it is immaterial whether the steam is first generated at the lower pressure or brought there by throttling. The real reason for generation at the critical point is a practical one, it being thereby made possible to eliminate any boiling (ebullition), thus permitting the use of small-bore tubes arranged in continuous coils without disengaging drums.

The 1,000-kw. experimental plant now nearing completion and soon to be erected at Rugby, England, is designed, in brief, to operate as follows: Feed water at a little above 3,200 lb. pressure is forced into the primary coils of the oil-fired steam generator. At a point about ninety per cent through these coils the temperature of 706 deg. is reached, whereupon the water changes instantly to saturated steam of the same specific volume and total heat. In traversing the remaining 10 per cent of the primary coils the steam is superheated to about 730 deg. F. It next passes through a reducing valve which brings the pressure down to 1,500 lb. and reduces[2] the superheat almost to zero.

The steam is then superheated to 788 deg. at 1,500 lb. in another set of coils and expanded to 200 lb. in a 464-hp. high-pressure turbine. The exhaust is reheated to 662 deg. and then further expanded to ½ lb. in a 1,210-hp. low-pressure turbine.

By employing the counterflow principle and using an air preheater operated by the flue gas, it is expected that a steam-generator efficiency of 80 per cent or better (not counting economizer or auxiliaries) will be obtained. The performance of the two turbines has been figured on the assumption that the high-pressure turbine will convert 60 per cent of the available heat drop and the low-pressure 70 per cent. Assuming a gross steam-generator efficiency of 80 per cent, an electric-generator efficiency of 95 per cent, and allowing a total of 108 electrical horsepower for the auxiliaries (consisting of draft fans 30 hp., feed pump 56 hp., condenser auxiliaries 20 hp., oil pump 2 hp.) the net over-all thermal efficiency of the plant would be 22.3 per cent, which is considerably higher than the efficiency obtainable in the best commercial low-pressure plants of the same capacity. The computations for this efficiency are given near the end of this article.

As a preliminary to any computations of thermal efficiency, it is obviously necessary to have some kind of a steam table or diagram giving temperatures, pressures, total heats and entropies over the range covered by the calculations. In order to have something definite to work with, the Benson Engineering Co. prepared a Mollier diagram which was based on that of Professor Stodola for all points to the right of 1.4-entropy line. This diagram was then filled out to the critical point by piecing together and averaging the results obtained by various investigators. The Mollier diagram thus prepared was in metric units. Fig. 4 is a small-scale copy in English units. As here given it is large enough for rough preliminary computations. In view of the fact that steam-table research now in progress will doubtless lead to a revision of values, it seemed unwise

*Assistant editor of *Power*.

[1] All pressures in this article are in pounds per square inch absolute and all temperatures in degrees F.

[2] It should be noted here that in throttling high-pressure steam the superheat decreases (or the moisture increases) with falling pressure until the neighborhood of 500 lb. is reached. After that the reverse effect takes place. This can be seen by a study of Fig. 4.

to give the present diagram an appearance of extreme accuracy by reproducing it on a larger scale.

All the calculations that follow are necessarily based on this diagram and are therefore to be considered as subject to revision when the properties of steam at high pressures and temperatures have been more accurately determined.

Before considering the Mollier and temperature-entropy diagrams, the relations shown in Figs. 1 and

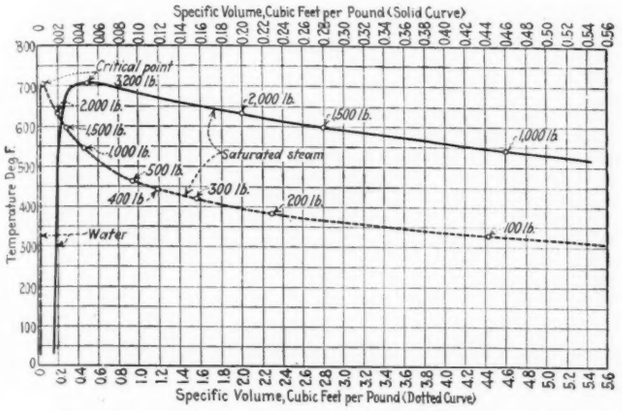


FIG. 1—SPECIFIC VOLUME OF WATER AND OF SATURATED STEAM

Solid line shows section of dotted curve with horizontal scale multiplied ten times. Water line on left and steam line on right meet on top at the critical temperature (706 deg.). Note the rapid change in volume of both water and steam near the critical point.

2 should be noted. Fig. 1 gives the specific volume of water and of saturated steam up to the critical temperature. Starting at 50 deg. with a specific volume of 0.016 cu.ft. per pound the expansion of the water is relatively slow at first (the specific volume at 400 deg. is 0.019 cu.ft.) and then increases more and more rapidly so that the expansion from 690 to 706 deg. is greater than that from 50 deg. to 690 deg. Saturated steam, on the other hand, expands at a rapidly increasing rate as the temperature decreases from around 700 deg. The highest point in the curve is the critical point where the steam line joins the water line and where the properties of steam are identical with those of water. The curves in Fig. 2 give the relation between the temperature and pressure of saturated steam. It should be noted that while the pressure increases more and more rapidly with rising temperature up to about 2,000 lb. per sq.in., the increase thereafter is practically constant at the rate of 17.5 lb. increase per degree. The uncertainty in this curve lies not so much in its path as in its end point. If either the critical temperature or critical pressure is once accurately known, the other may be closely determined from this curve.

The temperature-entropy diagram shown in Fig. 3 has been plotted from Fig. 4 and is, of course, subject to any errors that may exist in the latter. It is, however, probably close enough to give valuable information on the relative efficiencies obtainable with various methods of operation. The main "dome" is formed by the "water line" *AE* on the left and the "saturated-steam line" *ME* on the right, the two joining at the critical point *E* where, for the moment, steam and water are the same thing. Evaporation and superheat lines are shown for 200 lb., 500 lb., 1,500 lb. and 3,200 lb. (critical pressure). In addition the condensation line for ½ lb. (corresponding to 29-in. vacuum and 80 deg. condensate) is shown.

Some of the possible cycles are shown in the eight key sketches of Fig. 5, the lettering there corresponding to that in Fig. 3. All these are for theoretical plants with complete adiabatic expansion to a back pressure of one-half pound.

In each of these key sketches the thermal efficiency is the ratio of the upper shaded area to the total shaded area. A simple ratio of this sort is not, however, applicable in a plant where there is throttling, reheating or non-adiabatic expansion.

Sketch (1) is for a plant using 200-lb. saturated steam. Condensate at 80 deg. at *A* is heated up to 382 deg. at *B* and there evaporated at 200 lb. The dry-saturated steam at *H* is expanded adiabatically to *h* and then condensed at ½ lb. along the line *hA*. The heat absorbed in the process is the total area vertically below the feed-heating line *AB* and the evaporation line *BH*. That is, it is the area *a'ABHhh'*. The only heat rejected is to the condenser along the line *hA*, the amount of rejected heat being measured by the area *Ahh'a'*. The difference between these two areas is *ABHh*, which must therefore have been turned into useful work. The thermal efficiency is the ratio of heat turned into useful work to the total heat supplied, or the ratio of the upper area to the total area. In this case the ratio is 31.6 per cent. This is the limiting thermal efficiency of a plant operating between 200 lb. saturated steam and ½ lb. exhaust pressure, without superheat, on the complete-expansion Rankine cycle. As the initial pressure is increased, the lower area of rejected heat constantly decreases. The upper area of

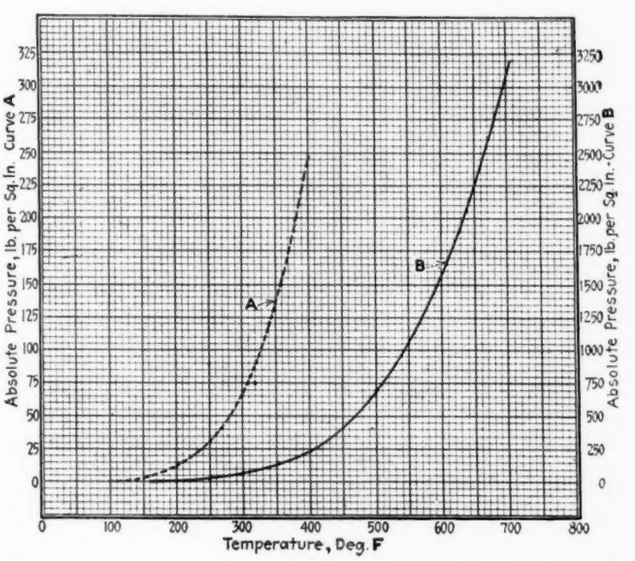


FIG. 2—VARIATION OF PRESSURE OF SATURATED STEAM WITH TEMPERATURE

The dotted curve shows the lower portion of the solid curve to an enlarged pressure scale. Note that the solid curve straightens out above 2,000 lb., after which the pressure increases at a practically constant rate of 17.5 lb. per degree F.

available heat increases at first and then decreases, so that at 3,200 lb. the upper area is less than at 200 lb.

The combined result of all these changes is that the efficiency (the ratio of the upper area to the total area) is 31.6 per cent at 200 lb., 36 per cent at 500 lb., 39.8 per cent at 1,500 lb. and then drops back to 37.8 per cent at 3,200 lb. This indicates that with saturated steam the point of theoretical best efficiency lies in the

neighborhood of 1,500 lb. The point of actual best efficiency would probably lie considerably lower because fluid-friction losses increase with the average density and wetness of the expanded steam, both of which are greater with higher initial pressures.

In these diagrams the percentage of moisture at any point is found by drawing a horizontal line through that point from the water line to the steam line and dividing the right-hand portion of this line by its total length. We then see, referring to sketch (4), that when steam is expanded adiabatically from the critical point, it immediately becomes practically 50 per cent wet and maintains this percentage, approximately, throughout expansion. In an actual turbine the moisture would

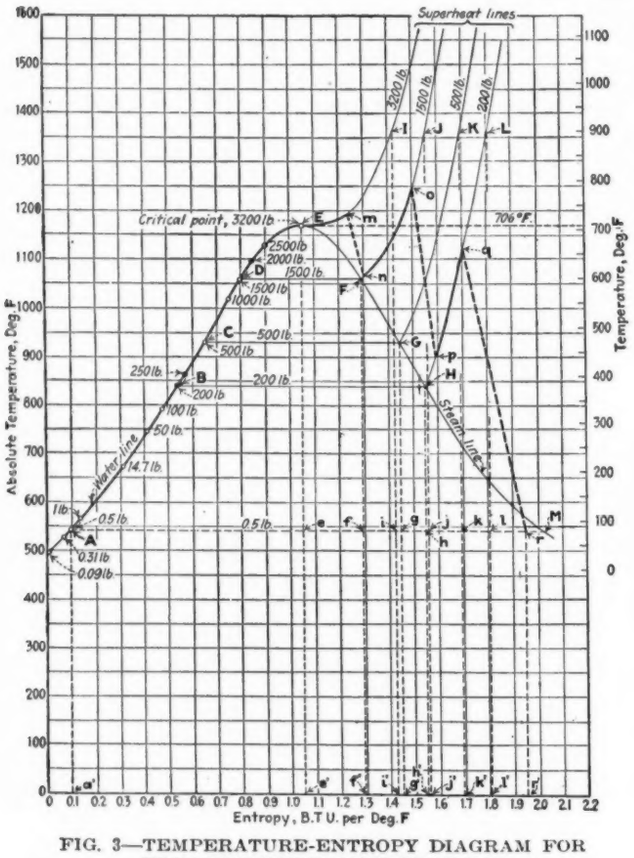


FIG. 3—TEMPERATURE-ENTROPY DIAGRAM FOR HIGH-PRESSURE COMPUTATIONS

Path *ABEmnopqrA* corresponds with total-heat-entropy diagram for Rugby installation as shown in Fig. 6.

decrease during expansion, but would still be so high as to cause serious difficulty. This indicates therefore that superheat is essential for practical operation with pressures at or near the critical.

The next four sketches repeat the same series of pressures, but the steam is in each case superheated to a maximum temperature of 900 deg. F., a temperature that many engineers believe may be practically employed with materials now available.[3] This superheating shows a marked increase in theoretical efficiency in every case and also shows a better efficiency at 3,200 lb. than at 1,500 lb. In all probability, however, an actual turbine operating under the conditions of sketch (8) would show no higher efficiency than one operating under the conditions of sketch (7), on account of greater fluid-friction losses at the higher pressure.

[3]This temperature is now exceeded by high-pressure plants operating in Sweden. Still higher temperatures have been employed in low-pressure drying plants.

There are many other possible combinations. For example, the feed water may be heated by steam bled off at one or more points during expansion. Although the subject is worthy of careful study, space does not permit a discussion of what happens to the theoretical temperature entropy diagram when stage heating is used in connection with extremely high pressures.

Laying aside the possible use of bleeder heating, there are various ways in which the theoretical efficiency can be increased with a fixed initial steam condition. One of the simplest is to reheat the steam between the high-pressure exhaust and the low-pressure inlet, or at one or more intermediate pressures during expansion. This produces only a small theoretical gain, but the actual gain is considerable because the higher superheat thus obtained in the lower expansion stages reduces fluid-friction losses.

The fact that the Benson plant invariably generates at 3,200 lb. and then brings the steam to the turbine inlet condition by a series of throttling and superheating operations has no significance so far as the theoretical efficiency is concerned. The total heat supplied is exactly the same as if the steam had been produced in the traditional manner. The reason for the Benson method of generating the steam lies entirely in practical considerations of the safety, first cost and operating characteristics of the steam generator.

Actual Operating Cycle of Rugby Plant

Fig. 6 shows the actual predicted operation of the Rugby plant as plotted from the Mollier diagram of Fig. 4. In this diagram the ordinates are total heat and the abscissas entropy. The point *E* represents one pound of water about 90 per cent through the primary coils of the generator at the "critical" instant when it flashes into steam. At this point the total heat is 903 B.t.u. and the temperature 706 deg. In passing from *E* to *m* the steam is superheated at 3,200 lb. to 730 deg. At *m* the steam leaves the primary coils and is throttled along the 1,130 B.t.u. line *mn* to *n*, where its pressure is 1,500 lb. and its temperature 605 deg. It is then superheated at constant pressure along *no* to *o*, where the temperature is 788 deg. and the total heat 1,350 B.t.u. Starting with feed water leaving the economizer at 150 deg. F. and containing 118 B.t.u., the total heat added to the steam up to the point *o* is 1,350 — 118 = 1,232 B.t.u. At *o* the steam enters the high-pressure turbine, wherein it is expanded to 200 lb. The available heat drop is 196 B.t.u., but only 60 per cent of this, or 117.6 B.t.u., is assumed to be utilized by the high-pressure turbine. The condition at the high-pressure exhaust is then represented by *p* and the path through the high-pressure turbine by *op*. The steam is next reheated to 662 deg. along the 200-lb. line *pq*. This reheating requires 118.8 B.t.u. It is then expanded to ½ lb. through the low-pressure turbine along the line *qr* figured on the basis of an available heat drop of 439 B.t.u. and an actual utilization of 70 per cent, or 307.3 B.t.u.

It is estimated that the over-all thermal efficiency of the completed Rugby plant (with low-pressure turbine and economizer) will be 22.3 per cent. The computations are shown in Table I. This efficiency represents a fuel saving of about 28 per cent as compared with a standard high-grade 1,000-kw. plant having an over-all thermal efficiency of 16 per cent.

The justification of the high steam-generator effi-

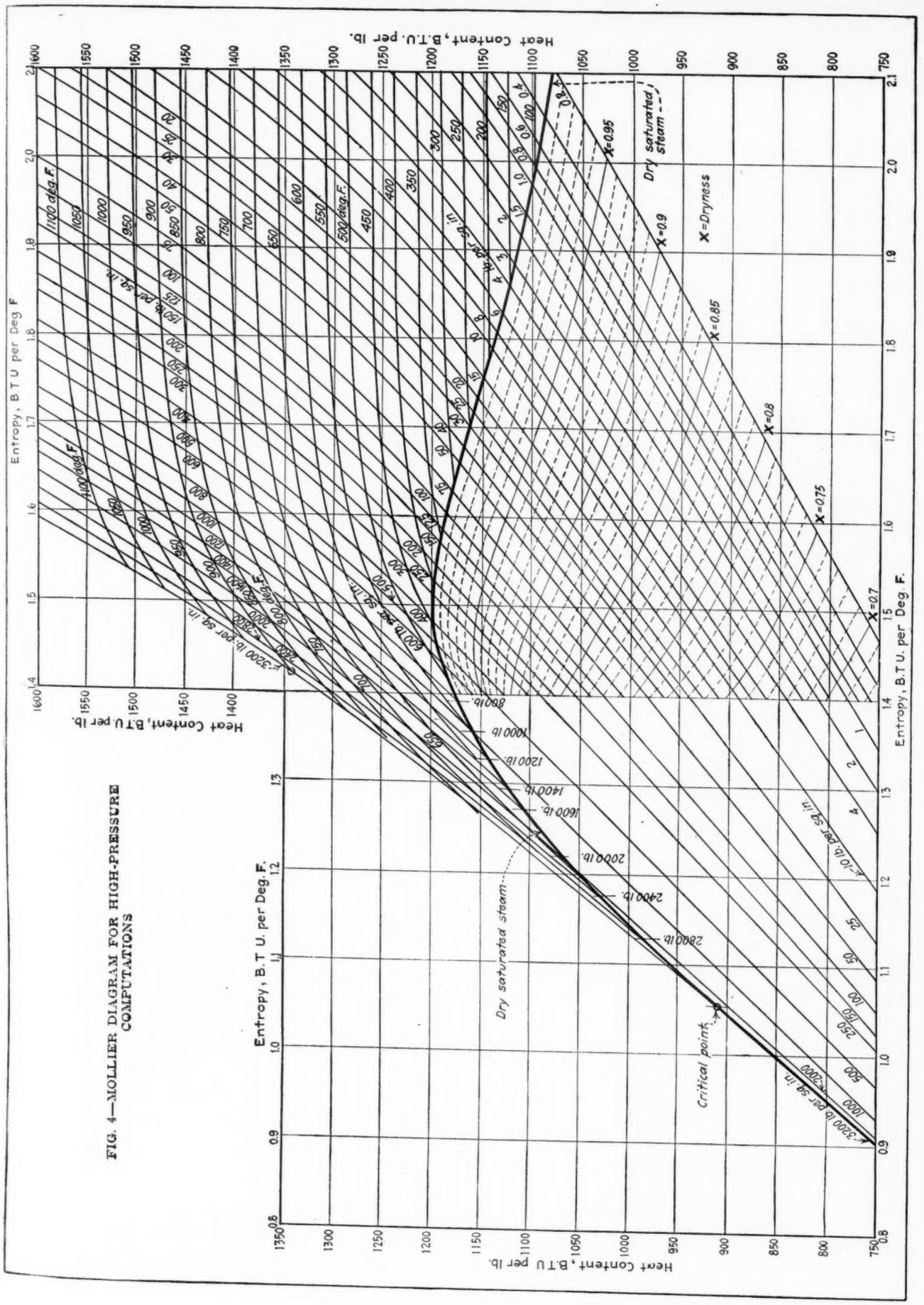


FIG. 4—MOLLIER DIAGRAM FOR HIGH-PRESSURE COMPUTATIONS

ciency assumed is found partly in the fact that the generator operates on the counter-current principle, with the exit gases in contact with the lower coils containing the low-temperature entering feed water. A large portion of the heat remaining in the flue gas is recovered by the air heater.

If the results obtained with the experimental plant are satisfactory, further improvement may be expected in future plants by taking advantage of increased maximum pressure and temperature, reheat, etc., or by using a combination mercury-steam plant.

The practical questions of cost, space required, operating simplicity, etc., have already been considered in the previous article. While, as there pointed out, only actual experience can definitely settle these questions, it is interesting to note that the builders of this plant expect that the substantial fuel saving due to high-pressure operation will actually be accompanied by a considerable decrease in first cost, weight and space occupied.

Particular attention has been given to the question of safety in the design and construction of the super-pressure steam generator. To reduce to a minimum any experimental hazard in this connection, the contract for the steam-generating coils has been awarded to a German company that has had fifteen years' experience in the construction of water "superheaters" for pressures and temperatures well up toward the critical point.

As an additional precaution a sample of each tube used has been tested by the National Physical Laboratory at Teddington. In addition to the ordinary hot-and-cold tensile test each sample was subjected to a special temperature test at high pressure. The test sections (4 ft. long) were filled with water, and the pressure was pumped up to 1,000 lb. per square inch.

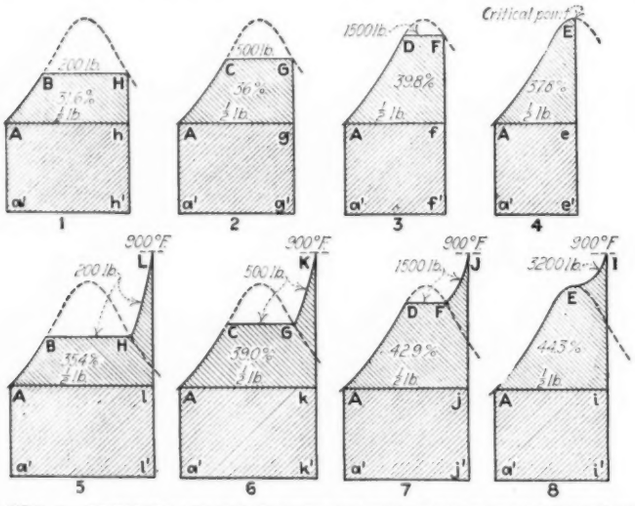


FIG. 5—TEMPERATURE-ENTROPY SKETCHES FOR PERFECT TURBINES OPERATING UNDER VARIOUS CONDITIONS ON THE RANKINE CYCLE

Initial and final conditions are indicated in each case together with thermal efficiency of perfect turbine. Letters correspond with those of Fig. 3. Note that theoretical efficiency with saturated steam is less for 3,200 lb. than for 1,500 lb.

The temperature was then raised to approximately 1,100 deg. F. At this temperature the pressure was gradually increased to 5,000 lb. and maintained at this figure for the remainder of the test. The temperature of the furnace was then slowly raised until fracture occurred.

The primary and superheating coils for the experimental plant are of carbon steel throughout. Chrome-nickel or alloy steel is, however, available for future work at higher temperatures. Where two different materials are used for different portions of the same coil, they will be joined by autogenous welding to make a continuous coil.

The tubing of the primary coils of the present installation has an internal diameter of 0.8 in. and an external diameter of 1.2 in. The superheater tubes will have the same internal diameter, but an external diameter of 1.6 in.

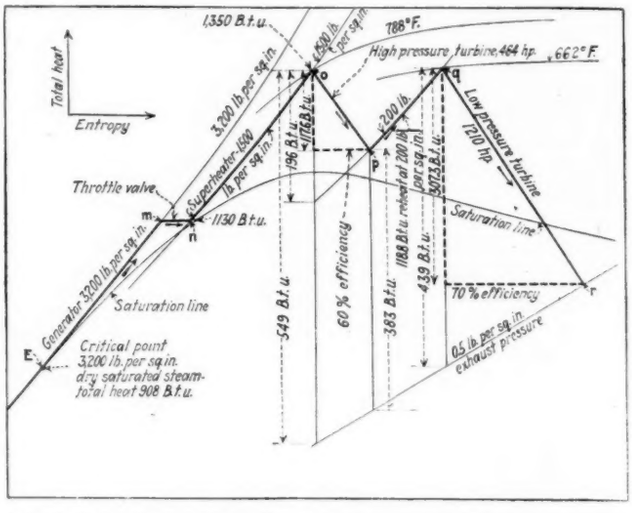


FIG. 6—TOTAL-HEAT-ENTROPY CHART FOR RUGBY PLANT

This is based on Figs. 3 and 4, and shows following steps:
E—Steam at critical point.
Em—Superheating at 3,200 lb.
mn—Throttling from 3,200 lb. to 1,500 lb.
no—Superheating at 1,500 lb.
op—Expansion through high-pressure turbine.
pq—Reheating at 200 lb.
qr—Expansion through low-pressure turbine to ½ lb. (29-in. vacuum).

It must not be overlooked that the explosion hazard depends on the probable seriousness of an explosion as well as the chance of its occurrence. The former depends on two factors—the amount of fluid under pressure and its available energy. As to the first point, the total amount of hot water and steam in the generator of the 1,000-kw. Rugby Plant will not exceed 0.25 ton. The available energy per pound is greater than at normal pressures but not in proportion to the pressure carried.

COMPUTATIONS FOR FINDING EFFICIENCY OF 1,000-KW. BENSON PLANT

Available heat drop, high-pressure turbine, B.t.u.		196.0
Available heat drop, low-pressure turbine, B.t.u.		439.0
Heat converted to power at turbine shaft:		
High-pressure turbine (196 × 0.60), B.t.u.	117.6	
Low-pressure turbine (439 × 0.70), B.t.u.	307.3	
Total, B.t.u.		424.9
Heat in steam at throttle, B.t.u.		1,350.0
Less heat in boiler feed at 150 deg. (from economizer), B.t.u.		118.0
Difference (net heat put in up to throttle), B.t.u.		1,232.0
Heat added in reheater, B.t.u.		118.8
Total heat supplied, B.t.u.		1,350.8
Combined turbine thermal efficiency (424.9 ÷ 1,350.8), per cent		31.5
Power developed at turbine shafts:		
High-pressure turbine, hp.	464	
Low-pressure turbine, hp.	1,210	
Total, hp.		1,674
Efficiency of electrical generator, per cent		95
Gross output electrical power (0.95 × 1,674), hp.		1,590
Less power output of auxiliaries, hp.		108
Net electrical horsepower		1,482
Steam-generator efficiency (not including economizer or auxiliaries), per cent		80.9
Over-all plant thermal efficiency (0.315 × 1,482 ÷ 1,674 × 0.80), per cent		22.3

Brush-Shifting Polyphase Series-Type Alternating-Current Motors—II

Construction and Connections—Limitations in Size and Speed—Relation of Speed, Torque and Position of Brushes—Test To Be Made When Putting the Motor into Service—Advantages of Brush-Shifting Motor

By R. A. JONES* and F. A. ANNETT†

IN THIS article the practical operation of the brush-shifting motor will be discussed. An article in the April 17 issue explained the fundamentals of this type of machine, therefore any question of principles in this article will be referred to the preceding discussion.

The brush-shifting polyphase series motor, Fig. 1, consists of a rotor, a stator and a current transformer connecting the two in series. A distributed winding is placed in the stator, Fig. 2, similar to that of an induction motor, and the rotor, Fig. 3, is similar in design and appearance to that of a direct-current motor, with the difference that its voltage is much lower. The transformer is of the series type having its primary in series with the stator of the motor and its secondary in series with the rotor through the commutator and brushes. In addition to supplying low commutator voltage, the transformer, being designed for high saturation, limits the no-load speed of the motor to a safe value, about 150 per cent speed.

In Fig. 4 is shown, diagrammatically, a two-pole three-phase brush-shifting series motor. The secondaries of

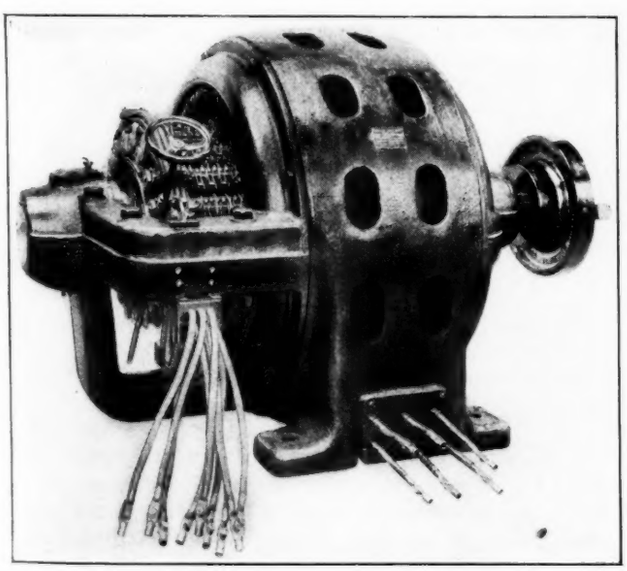


FIG. 1—SPEED OF MOTOR ADJUSTED BY SHIFTING POSITION OF BRUSHES

the transformers are connected in star and to the three brushes on the commutator. In this type of motor the brush yoke is arranged for as many brush studs as there are pairs of poles times the number of phases. In a three-phase rotor there will be be three brush studs for each pair of poles and in a six-phase rotor six brush studs for each pair of poles. In a six-pole six-phase motor there will be $3 \times 6 = 18$ groups of brushes on the commutator. If the armature is series-connected

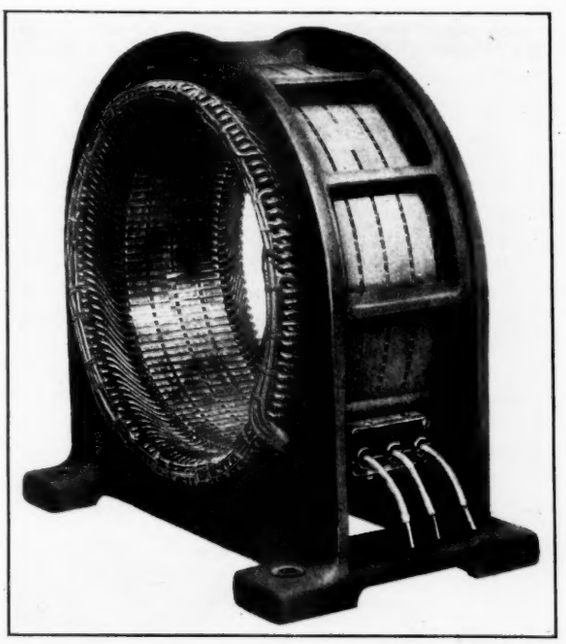


FIG. 2—DISTRIBUTED STATOR WINDING, SIMILAR TO THAT USED IN AN INDUCTION MOTOR

or in a parallel-wound armature with equalizing connections to every commutator bar, the motor may be operated with no more brushes than there are phases. On motors having a large number of poles, sometimes some of the brush studs are left off and the remaining studs allowed to carry the current of two or more. Increasing the number of rotor phases decreases the commutation voltage and the current per phase, thereby improving commutation and increasing the commutator's capacity. The interaction of the magnetic fields of the rotor is such that there is produced in the rotor windings a voltage that tends to improve the power factor.

The greater the number of rotor phases the more difficult the constructing of the rotor transformers. Twelve phases provide satisfactory commutation and sufficient small current per phase for the majority of cases, so that there is no necessity for a greater number. However, twelve-phase rotors are not always used, six and nine phases being more common.

Where wide ranges of speed are required and the torque load decreases with the speed, as with fans and

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similar loads, it is common practice to connect the stator windings in delta, Fig. 5, for the higher speeds and in star for the lower speeds, Fig. 6. The rotor connections are not changed when the stator connections are changed, but remain the same under all conditions. Changing the stator connections from delta to star is equivalent to reducing the voltage. This decreases the brush shift necessary to obtain a desired reduction in speed, thereby improving the speed-torque characteristics of the motor. Also the equivalent voltage reduction reduces the magnetizing current, which greatly improves the power factor, and there is an improvement in the efficiency.

Supplying Excitation for the Motor

As part of the excitation of the motor is supplied to the rotor through the transformers, the power factor of the line is better than if induction motors were used, which require all the excitation to be supplied through the motor stator. Since it is becoming the practice with central stations to penalize their customers for low power factors, this characteristic of the brush-shifting motor is worthy of consideration. Polyphase brush-shifting series motors can be designed to operate at full load and synchronous speed with leading current.

In fact, the main advantages of the motor, neglecting the extreme flexibility of control, are the high efficiency and power factor at reduced speeds. Typical comparative efficiency and power-factor curves for brush-shifting and slip-ring motors when driving a fan or similar loads, are given in Fig. 7. One hundred per cent speed for the brush-shifting motor is equal to 12½ per cent above synchronism, while for the induction motor it equals full speed, or approximately 96 per cent synchronism. This comparison, Fig. 7, assumes that the motors are driving equal loads, but that the machine driven by the slip-ring motor is designed for a slightly lower speed. At 100 per cent speed the slip-ring motor efficiency is slightly higher, but as the speed decreases, the loss in

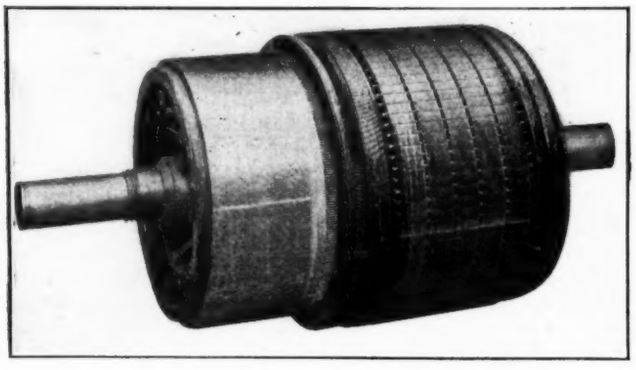

FIG. 3—ROTOR OF BRUSH-SHIFTING MOTOR

the secondary resistors causes the efficiency to drop off rapidly.

For the same speed a 50-cycle motor would have 50 ÷ 25 = 2 times as many poles as a 25-cycle motor, so that with the same number of brushes on the commuataor there will be twice as many phases in the rotor of the 25-cycle machine as in the 50-cycle. For example, a 20-pole 50-cycle motor will operate at the same synchronous speed as a 10-pole 25-cycle motor; namely, 300 r.p.m. If the rotor of the 50-cycle machine is wound for six phases, there will be 10 × 6 or 60 groups of brushes on the commutator, where on the 25-cycle machine with a twelve-phase rotor there will be the same number 5 × 12 or 60 groups. Therefore, with the 25-cycle machine with the same number of brush groups on the commutator there is double the number of phases as with the 50-cycle machine. As previously pointed out, increasing the number of rotor phases improves the motor's operation. For this reason 25-cycle circuits have an apparent advantage for polyphase brush-shifting motors over circuits of higher frequencies. However,

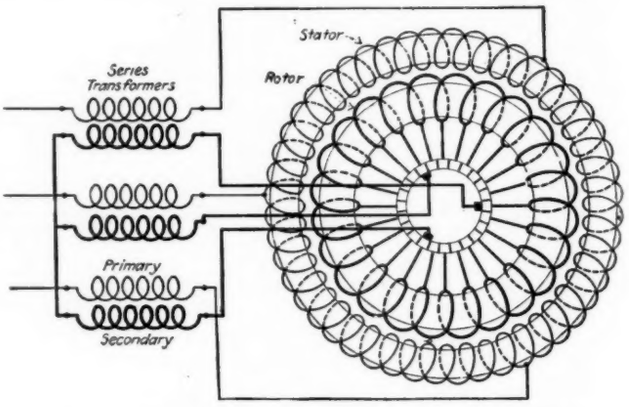

FIG. 4—SCHEMATIC DIAGRAM OF MOTOR AND TRANSFORMER CONNECTIONS

this is more theoretical than practical, since about 90 per cent of the large number of these motors in service are operating on 60-cycle systems, and as these represent both the largest and smallest sizes, there can be little doubt as to the ability of the 60-cycle motor to give satisfactory service.

Sizes, Speeds and Voltages

The polyphase brush-shifting motor has been built in sizes ranging from 10 to 300 hp. at speeds from 200 to 1,200 r.p.m. and for voltage on the stator windings up to 6,600 volts. It has been found by experience that the maximum capacity for which these motors can be built is 30 hp. per pole for 60 cycles and 70 hp. per pole for 25 cycles. These limits are established by the currents that can be satisfactorily handled on the commutator, and set the maximum size of 1,200-r.p.m. motors at 175 hp. and 600 r.p.m. machines at 350 hp. For driving forced-draft fans in power plants, they have been built for 900 r.p.m. at 185 hp., and for driving mine fans for 600 r.p.m. at 252 hp.

As previously mentioned, these motors are designed so that 100 per cent speed is obtained about 12.5 per cent above synchronous speed. This means that in a six-pole 60-cycle motor, which will have a synchronous speed of 1,200 r.p.m., the maximum speed of the motor will be 1,200 plus 12.5 per cent of 1,200, or 1,350 r.p.m. While the degree brush shift for any specified speed may not be the same for motors of different rating, the following example is typical and illustrates the amount of brush shift required to produce a given speed change. With the motor developing full-load torque and the brushes set approximately 8 electrical degrees from the live neutral, the speed will be 12½ per cent above synchronism. Assuming this motor to be a six-pole, 1,200-r.p.m. machine, three electrical degrees will be equivalent to one mechanical degree.

Synchronous speed at 100 per cent torque is obtained with the brushes set at about 15.75 electrical degrees ahead of the live neutral. With the brushes set 45 electrical degrees from the live neutral when the motor is

developing 100 per cent torque the speed will be about 65 per cent of synchronism, and at 67.5 electrical degrees from the neutral and 100 per cent torque the speed is about 35 per cent synchronism. If the synchronous speed is 1,200 r.p.m., then with the brushes set at 67.5 electrical degrees from the live neutral the speed will be about 1,200 × 0.35, or 420 r.p.m. This would be about the maximum brush shift for a motor driving a constant-torque load. If as the speed decreased the torque also decreased, as would be the case with a fan, then at 40 per cent torque the brushes would have to be shifted about 90 electrical degrees from the live neutral to obtain 35 per cent synchronous speed. With a fan load, if the speed is reduced below approximately 70 per cent synchronism, the stator windings and primary connections of the transformers should be changed from delta to star, as indicated in Figs. 5 and 6. For load having constant torque the lower limit of speed is about 65 to 75 per cent below synchronous speed.

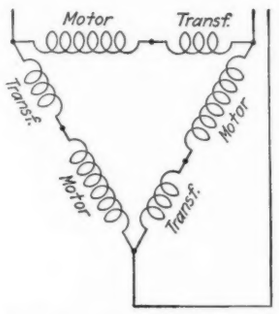

FIG. 5—DIAGRAM SHOWING TRANSFORMERS AND MOTOR WINDINGS CONNECTED DELTA

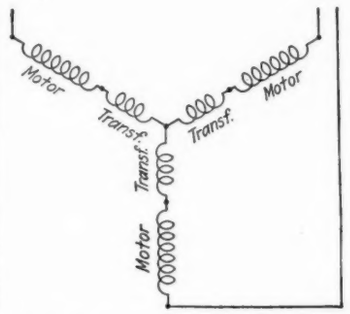

FIG. 6—DIAGRAM SHOWING TRANSFORMERS AND MOTOR WINDINGS CONNECTED STAR

Starting Torque Is Influenced by Position of the Brushes

The starting torque developed by the motor is influenced by the position of the brushes. With the brushes set at about 16 electrical degrees from the live neutral, a starting torque of about 350 per cent full load is obtained, with a current equal to about 425 per cent full load. One-hundred per cent starting torque can be obtained with about 164 per cent full-load current and the brushes set at about 60 electrical degrees from the live neutral. If the motor were started with the brushes set in a position to give 50 per cent synchronous speed at 100 per cent torque, 164 per cent starting torque could be obtained and the inrush current would be 250 per cent. These values are for a 10-hp. 1,200-r.p.m. motor with the stator delta connected, and although the figures cannot apply specifically to motors of other ratings and speeds, they show what may be expected of the brush-shifting polyphase series motor.

In the polyphase induction motor torque is produced by the stator's rotating magnetic field inducing into the rotor's winding a current that reacts on the rotating field, the direction of rotation being determined by the direction in which the magnetic field revolves. Since a rotating field cannot be produced by a single winding, a polyphase induction motor will not start single-phase. In the stator of a polyphase brush-shifting motor a rotating magnetic field exists as in the induction motor, but, as has been previously shown, torque is produced by the reaction between the stator and rotor poles, the position of the latter being determined by the position of the brushes on the commutator, therefore the polyphase motor can produce a starting torque on single-phase operation.

When the motor is properly connected—that is, so that the same relation exists between the rotor and stator windings for each phase—the motor will develop the same torque and take the same current from the line, when operating on any one of the phases. This is the first test to make on the motor after it has been connected up according to the diagram of connection. Disconnect one phase from both the stator and rotor and with the brush in a position where the rotor can turn, start the motor; if it develops the same torque on all three phases and turns in the same direction, it is correctly connected.

Direction of Stator's Magnetic Field

The direction in which the stator's magnetic field rotates has no influence on the direction of the rotor's rotation, this being determined by the position of the brushes. However, the motor should be connected so that the rotor will turn in the same direction as the rotating magnetic field in order to obtain good commutating characteristics and power factor. When the mechanical rotation and the magnetic field are in the same direction, maximum current will be obtained at starting, and as the motor comes up to speed the current will decrease to normal. If the motor is so connected that the magnetic field rotates opposite to the rotor, the starting current will not decrease as the rotor comes up to speed, but may remain practically constant or increase.

A test for this condition can be easily made with an ammeter. After the single-phase tests have been made and the current relation obtained between the rotor's direction of rotation and that of the stator's magnetic field, the motor may be put into service. If it is found that the magnetic field is rotating in the wrong direction, the condition can be corrected by interchanging any two-phase lead at the line-switch on a three-phase circuit. On a four-wire two-phase circuit interchange the line wires of either phase, and on a three-wire two-phase circuit interchange the two outside line wires.

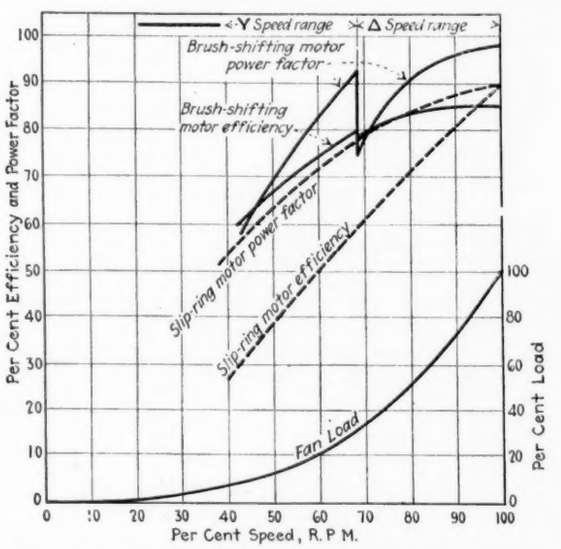

FIG. 7—COMPARISON BETWEEN THE POWER FACTOR AND EFFICIENCY OF A BRUSH-SHIFTING AND A SLIP-RING MOTOR

The direction of rotation can be reversed by shifting the brushes past either neutral point after the line switch has been opened. It is not possible to have the motor connected to the line and bring it to rest by moving the brushes to the dead neutral and then reversing the direction of rotation by shifting them beyond this point, on account of poor commutation at the low speeds. In practice, on account of operating the motor with the brushes set nearer the live than the dead

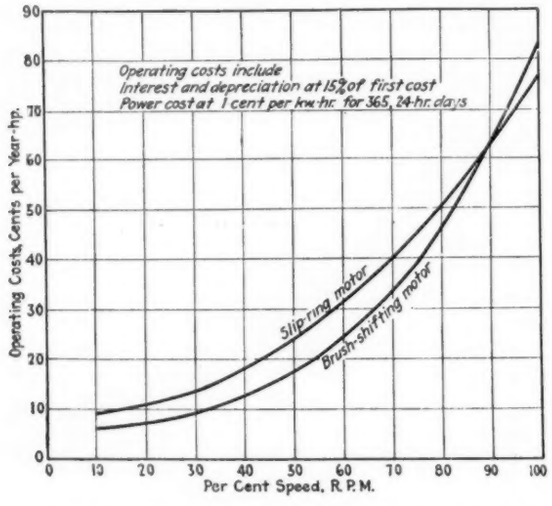

FIG. 8—COMPARISON BETWEEN THE COST OF OPERATING A BRUSH-SHIFTING AND A SLIP-RING MOTOR AT 70 PER CENT SPEED

neutral, the brushes are shifted by the live neutral and two of the line leads interchanged to reverse the direction of rotation. If the line leads are not interchanged when the direction of rotation is reversed, the stator field will rotate opposite to the rotor, causing a lowering of the motor's speed for the same brush setting and resulting in poor commutation and power factor.

Systems of Control Available

While the speed control of the motor is obtained simply by shifting the brushes, several systems of control have been devised, ranging from a simple handwheel manually operated, to an automatic system involving no attention. For the larger motors or installations requiring start-and-stop push-button control of the speed, the brushes are shifted by a pilot motor geared to the brush yoke. Holding down the "fast" or "slow" button until the desired speed is reached is all that is necessary to obtain any speed in the range. For full-automatic control, such as is used with boiler forced-draft fans, for instance, an equipment has been developed which provides starting or stopping the pilot motor by means of a pressure governor.

A further advantage in the use of the brush-shifting motor is the reduction in power costs. With a 100-hp. fan unit operating four hours a day at 100 per cent speed, eight hours at 85 per cent speed, eight hours at 65 per cent speed and four hours at 50 per cent speed, the power saving at one cent a kilowatt-hour equals $540 a year, which, capitalized at 15 per cent for interest, depreciation, etc., justifies an additional expenditure of $3,600 for the brush-shifting equipment over that for the wound-rotor motor. This is a conservative estimate, for in the majority of cases the cost of power exceeds one cent per kilowatt-hour; but even so the additional expenditure that is justified would practically cover the complete charge for a new motor.

The importance of this increased efficiency for varying speed, fan or similar drives is shown in Fig. 8, where the operating cost per horsepower per year is plotted against speed. This operating cost includes interest on the capital investment and depreciation at 15 per cent and a power charge of one cent per kilowatt hour input. This shows that above 91½ per cent speed the brush-shifting motor is generally the more expensive to operate, but for operation at any speed below this, it is the cheaper equipment. Assume, for example, a 100-hp. motor operating continuously at 70 per cent speed. The operating cost per horsepower per year for the slip-ring motor is about $40 and for the brush-shifting motor about $34. Therefore, with a 100-hp. motor there would be a saving of about $600 a year and at the end of six years the brush-shifting motor would have paid for itself.

Comparatively Recent Installations

Three comparatively recent installations employing automatic type of control are at the Springdale and Windsor Stations of the West Penn Power Co. and the Hell Gate Station of the United Electric Light and Power Co. The equipment at the Springdale Station, which has been operating for about three years, consists of five 150-hp. 720-r.p.m. 2,200-volt motors driving boiler forced-draft fans. The control is arranged to vary the speed automatically in accordance with the variation in air pressure over the fire. In the Windsor Station there are eight 125-hp. motors driving forced-draft fans. At the Hell Gate Station there are twelve 175-hp. 450-r.p.m. 2,200-volt motors driving induced-draft fans and eight 185-hp. 720-r.p.m. 2,200-volt motors driving forced-draft fans. The control is arranged for push-button start, stop and speed regulation.

The practicability of the brush-shifting type of motor for a variety of drives has been thoroughly demonstrated by several machines that have been in operation for seven or eight years. So far the majority of applications have been to mine fans, ventilating fans, boiler-draft fans, pumps, printing presses and textile-mill machines such as tenter frames, spinning frames and cloth-printing machines. There is no reason, however, why these motors should not be suitable for any variable-speed drive where limited series characteristics are not objectionable.

The form of energy we call heat is really nothing but the energy of molecules vibrating back and forth. As more heat is put into a body its temperature rises; that is, the molecules move more rapidly. When a certain point is reached the vibration is so violent that the molecules no longer hover about the same spot, but move around with more or less freedom, though still held fairly close together by their mutual attractions. When this happens we say that the solid has melted and become a liquid. With further addition of heat the temperature and speed of the molecules continue to rise until they overcome their mutual attractions and fly around freely like bullets, only changing their direction when they bump into one another, or the walls of the containing vessel. The liquid has now become a gas, and it is this incessant bombardment of the molecules that produces the pressure that a gas exerts on anything that touches it. This pressure increases with an increase of the temperature, weight or molecular weight of the gas, because these increase the bombardment.

The Influence of Radiant Heat on Furnace Design

By Prof. A. G. CHRISTIE*

MODERN boilers and furnaces are designed for the highest efficiency under given operating conditions, and in service every attempt is made to secure such efficiencies. Any arrangement that may promise still higher efficiency deserves careful study by every power-plant engineer. Reference has been made frequently, in recent discussions, to the influence of radiant heat on furnace operation and boiler efficiency, but no attempt has yet been made to analyze this effect in detail. The following paragraphs will discuss the principles of radiant heat and its effects and indicate how these principles may be applied to improve boiler efficiency.

Let us first consider how heat may be transferred from the fuel to the water in a boiler. Suppose the fuel were burned in a chamber separate entirely from the boiler, as is the case in a waste-heat boiler. Then the heat is carried to the boiler by the hot gases which, on coming in contact with the tubes give up their heat to be conducted through the metal to the water inside. The hot gases act as heat carriers. This method of heat transfer can be called "convection and conduction," consisting of the mass transfer of heat.

BY SIMPLE analogies the author pictures the behavior of radiant heat waves and their effect on various substances, leading up to an analysis of radiant heat in boiler furnaces. He suggests designing the furnace with a maximum amount of boiler-tube surface exposed to the fire in order to take up the greatest amount of radiant heat, and cites tests to show that the supposed chilling effect would not decrease the boiler efficiency. Instead, such protection of the side walls would permit the use of less excess air and make for greater over-all efficiency.

Most persons have enjoyed sitting around a roaring camp fire on a fall night when frost is in the air. The parts of one's body toward the fire will become intensely warm, while those parts away from the fire will feel the cold of the air. If one turns around, the part facing the fire will warm up and the side away from the fire will cool off. It is apparent that heat in some form is being transferred from the fire through the cold air to those parts of the body that are directly exposed to the fire. If one observes closely, one will note that one's breath shows frosty in the air, and it can be readily shown that this surrounding air is not appreciably heated by the fire. The heat energy one receives from the fire must, therefore, pass through this air without heating it. In this manner it is absolutely different from the previous case, where the hot gas transfers the heat by convection.

The heat from the glowing camp fire is known as radiant energy and passes through the intervening air in the form of energy waves similar to, but of different wave length from, the better-known waves of light and sound and the electrical waves popularly known as "radio waves." These radiant energy waves pass off in straight lines in all directions from the glowing fire and will strike and be received only by those surfaces directly exposed to the fire.

It is not necessary for the purpose of this article to enter into a discussion of the exact nature of these waves other than to consider how they are received by various substances. We have already seen that these heat waves pass through the air without heating it. The heat from the sun comes to us in the same way. Although this heat passes through the air, it does not heat it appreciably. It is well known that the air becomes colder as one rises above sea level. Aviators frequently suffer from intense cold at high altitudes even on a midsummer day. A substance such as air is said to be transparent to radiant heat. Glass, rock-salt crystals and several other substances are also quite transparent to these heat waves. Water, on the other hand, though transparent to light waves, is not transparent to heat waves and in fact readily absorbs such waves that fall upon its surface. As a result shallow ponds and lakes heat up rapidly in summer after a few days of bright sunshine. When a substance absorbs all these radiant heat rays, the phenomena that takes place may be assumed to be as follows: The waves beat upon the molecules at the surface of the substance. These molecules already are in a certain state of vibration corresponding to their temperature. If their natural period of vibration is in "tune" with the radiant energy wave, their speed of vibration will be increased by the extinguishing of the waves and the absorption of their energy. Increased molecular vibration is synonymous with increased temperature; hence the receiving body heats up. A substance that does not permit radiant heat to pass through it is said to be opaque to radiant heat. Radiant energy falling on such substances will be either absorbed or reflected. No actual body is a perfect absorber although rough black bodies, particularly lampblack, approach this condition. Light-colored, polished bodies such as mirrors are excellent reflectors. Other opaque substances, such as certain non-conducting materials like firebrick, become heated appreciably at the surface only and radiate again from this surface. All bodies radiate heat to a greater or less degree.

Those opaque bodies that are good absorbers are good radiators, while those that are poor absorbers are generally good reflectors. The ideal black body is the best radiator and also the best absorber. Hence, dark metallic surfaces will in general be good absorbers. Coal is a good radiator. Arches of firebrick—poor absorbers

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—are arranged in many furnaces to reflect radiant heat on the incoming coal in order to ignite it. The capacity of the black coal to absorb heat makes this ignition possible. Reflectors of radiant heat are then of two classes—either those polished surfaces that reflect the radiant heat rays as a mirror reflects light rays, or those opaque substances that are very poor conductors of heat and whose outer surfaces only heat up and act as reflectors to any further radiant heat waves that are incident upon them.

Heat Rays in the Furnace

Let us now apply these ideas on radiant heat to an actual furnace. The bed of the burning incandescent coal sends out radiant heat in all directions. Some of this reaches the tube surfaces exposed to the fire. Some more radiant heat is absorbed on its way to the tube surfaces by the flames and gases above the fuel bed, for it is well known that water vapor and carbon dioxide in the gases readily absorb radiant heat. The flames, however, also radiate heat so that much of the radiant heat from the coal bed ultimately gets to the tubes or the walls. Other radiant heat rays from the coal bed fall directly on the inner surface of the fire brick and, after heating it to incandescence, are radiated again partly to the tube surface and partly back into the fuel bed. This reflected heat from the side walls is often the cause of excessive fusing and clinkering of the ash and is thus detrimental to furnace operation. Furthermore, a large amount of heat may be wasted when this excessively hot ash is dumped into the ashpit.

The rates of heat transfer by convection and conduction and by radiant heat must be understood in order to realize the important part played by the latter. Tests have indicated that the rate of heat transfer by convection increases with the velocity of the gases over the tubes. In other words, "scrubbing action" must be set up on the tube surfaces to get high heat transfer. Radiant heat may be absorbed by surfaces that do not come in contact with the hot gases as well as by surfaces in their path. An example of this is the warming of a person by the camp fire previously described. Few quantitative tests data are available regarding the rates of heat transfer by convection and radiant heat. Royds, in his new book, "Heat Transmission by Radiation, Conduction and Convection," records some valuable data on this subject. Such reliable test data as are available indicate that with the same temperature difference the rate of heat transfer by radiant heat at the tube surface is several times that which may be expected from convection under usual furnace conditions.

The theoretical rate of heat transfer by radiant heat R per square foot is usually by Stefan and Baltzman's law, which is as follows:

$$R = 1{,}600 \left(\frac{T_1}{1{,}000}\right)^4 - \left(\frac{T_2}{1{,}000}\right)^4$$

where

R = B.t.u. per sq.ft. per hour;

T_1 = Absolute furnace temperature in degrees F. = 459.6 + t; where t = observed temperature;

T_2 = Absolute temperature of surface receiving radiant heat, degrees F.

This formula applies only to a black body. In an actual furnace with water tubes the rate of absorption will be from 0.2 to 0.25 of the figure given, depending on the nature of the surface. With tube surfaces protected by only a thin layer of light-colored soot, which in itself is a poor heat conductor, the heat transfer may be as low as 0.1 of that given by the preceding formula.

Suppose the furnace temperature were to increase, the rate of heat transfer R would increase at a rapid rate, for $\frac{(T_1)^4}{1{,}000}$ will increase at a rapid rate, while $\frac{(T_2)^4}{1{,}000}$ remains constant. It is, therefore, apparent that the highest furnace temperature commercially possible is conducive to the greatest transfer of heat by radiant energy. It would seem obvious that furnaces should be designed with large heat-absorbing surfaces surrounding them so that most of the heat might be taken up in the form of radiant energy, as a given amount of surface will absorb the greatest amount of heat by this means.

Radiant Heat Should Be Directed

It is well to remember that there are certain conditions under which reflected heat is necessary and advisable, as for instance, to ignite anthracite on forced-draft chain-grate stokers, and to dry out and ignite lignite coal or other low-grade fuel entering stokers. Under such conditions it is necessary to use a portion of the radiant heat from the fuel for this purpose, but care must be taken to design the brickwork so that heat is reflected only to those parts needing this heating.

With the usual design of furnace, it is not advisable to obtain the highest temperature possible in the furnace, for the firebrick walls will not stand such temperatures. It is, therefore, necessary to admit excess air through the fire to reduce the furnace temperature to a degree that the walls will stand. On account of the limitations of such brickwork one is, therefore, compelled to deliberately sacrifice boiler efficiency. In powdered-coal furnaces this difficulty has been partly overcome by using hollow air-cooled brick walls and partly by the use of water screens so that high furnace temperatures are now possible with the minimum amount of excess air. Hence, improved boiler efficiencies have been obtained with powdered coal. The heat taken up by the air circulating through the hollow furnace walls is returned to the furnace and tends to raise the furnace temperature. If it were feasible to maintain the furnace walls without this air cooling, it would be possible to secure the same degree of preheating of entering air and probably even more preheating by placing an air economizer in the flue gases. Such a recovery of waste heat would still further increase plant economy, and it would, therefore, seem desirable to effect such air preheating.

It has already been shown that the greatest rate of heat transfer from fuel to boiler surface is by means of radiant heat. Why is it not possible to design the furnace with the maximum amount of boiler-tube surface exposed to the fire in order to take up the greatest amount of this radiant energy? In other words, why not make the walls of the furnace of banks of water tubes with brick only filling the interstices? The tubes on the side walls may be so spaced that they will maintain the intervening brick wall below fusing temperatures. Other forms of side-wall construction may be adopted, such for instance as the water-leg of locomotive boilers, or types of protected tubes of various sorts may be used. It is a reasonable deduction from the previous reasoning that such construction will provide

higher boiler efficiency. What objections may be raised to this plan?

We have been told that such construction would so chill the fire that high furnace temperature and, therefore, high boiler efficiency could not be obtained. This is a view widely held by engineers which, however, does not seem to be fully borne out by facts. Physicists have frequently shown that the radiant heat emitted by a flaming gas jet comes principally from the outer surface of the flame and that a greater part of the radiations from the interior portions of the flame never penetrate to the surface, but are absorbed by the intervening gas. Consider the case of the highly luminous powdered-coal flame. A fine coal particle leaving the burner is first highly heated by radiant energy from the flame and then starts to give off its own volatile matter which combines with the surrounding oxygen and develops heat. This heat causes the coal particle to glow. If this particle is on the outer surface of the flame, it may radiate some of its heat from its glowing surface to the furnace walls. But this heat is being replenished at the same time by the combustion of additional volatile matter and finally of its own content. The coal particle has meanwhile made the circuit of the furnace without drawing appreciably on the radiant energy of its neighbors. In other words, the combustion of the fuel in the outer envelope of flame will furnish the heat radiated to the adjoining walls without appreciably affecting the interior of the flame. Hence high furnace temperatures will be maintained even with large radiant-heat absorbing surfaces.

Data have been presented at times which indicate that changes in baffling to reduce the surfaces absorbing radiant heat, have increased boiler efficiency. In every case it is evident that certain other factors were influenced by this change in baffling, and if all the facts were known it is almost certain that these other factors had a predominating influence on the change in boiler performance.

Absorption of Radiant Heat Does Not Reduce Furnace Temperature

There is little information available on the effect of radiant heat in pulverized-coal furnaces. However, some recent experience and tests on radiant-energy superheaters indicate that the absorption of radiant energy in the furnace has no deleterious effect on furnace temperatures. Facts are on record which indicate that the presence of large radiant-heat absorbing surfaces cause no lessening of boiler efficiency. Some of these facts will now be presented.

There is an account in *Engineering*, Feb. 18, 1902, of trials conducted by a committee appointed by the British Admiralty on the Scotch Marine boilers on the S.S. "Saxonia." After allowance for the air preheated, the boiler and furnace efficiency was stated as 78.3 per cent. The Morrison furnace of a Scotch boiler makes a wholly inclosed water-cooled fire chamber. Another series of tests on Scotch boilers reported in *Mechanical Engineering*, April, 1923, show remarkably good results. Boiler and superheater efficiencies of 73.9 to 77.9 per cent were secured with hand-fired coal and of 80.2 to 84.6 per cent with fuel oil. If this effect of water-cooled surface on furnace temperature were serious, it would hardly seem possible to secure such results.

Many tests on locomotives at the St. Louis Exposition gave boiler efficiencies over 75 per cent, and several were over 78 per cent. In these boilers the firebox is completely surrounded by water-cooled radiant-heat absorbing surfaces. Tests on Manning boilers where the furnace is totally inclosed by water-cooled walls, have also shown high boiler efficiencies. Boiler and superheater efficiencies ranging from 82.2 to 86.1 per cent were obtained with powdered coal on tests of boilers at the Lakeside station, Milwaukee (*Power*, Dec. 19, 1922). These latter results suggest that the presence of the additional radiant-heat absorbing surfaces of the water screen placed inside the furnace had no injurious effect on furnace performance. It should be particularly noted that these results were obtained with pulverized fuel.

A new house-heating boiler designed to utilize radiant heat to the greatest possible extent was tested in 1921 in the laboratories of Johns Hopkins University and boiler efficiencies over 80 per cent were obtained. Many other boiler tests made by recognized authorities on internally fired boilers, such as the Lancashire and similar types, and on those with locomotive fireboxes might be quoted as further evidence that as high boiler efficiencies are possible with boilers having large radiant heat absorbing surfaces as with standard boilers. Also tests on return-tubular boilers and others where large water-cooled areas are exposed to the furnace, have frequently shown such high efficiencies that one is convinced that the presence of these radiant-energy absorbing surfaces must have had a beneficial effect on the boiler efficiency. Furthermore, many of these boilers and grates were operated with much higher excess air than one would use, for instance, in a powdered-coal furnace, so that the furnace temperature was never so high as might be possible nor the efficiency so good as would be obtained with lower excess air.

Analogy of the Junker's Calorimeter

The effect of radiant heat on boiler efficiency can be further studied by considering carefully the functioning of that well-known instrument, the Junker's Calorimeter, which is used for determining the heating value of gas and of oil fuels. The calorimeter consists of an annular cylinder with the annular space filled with numerous small tubes provided with a hollow-walled cover on top. All the hollow spaces in the walls and top of the calorimeter are filled with water. The burner is adjusted to the proper air-gas mixture outside the calorimeter and is then inserted inside the bottom of the hollow water-cooled cylinder. Baffles on the burner stem reflect all radiant heat rays back into the calorimeter. The products of combustion pass to the top of the calorimeter and then down through the small tubes to the outlet. The true B.t.u. value of the gas is found by adjusting the water temperature and flow so that these waste gases leave at or about room temperature.

Several interesting phenomena relating to the effects of radiant heat may be considered from a study of this instrument. In the first place, the flames are almost entirely surrounded by radiant-heat absorbing surfaces, and should therefore be subjected to any cooling action that might possibly occur. In the second place, the calorimeter can be regulated to measure the true heat value of the gas; that is, the whole of the heat in the gas. In fact, this instrument is the recognized standard for the measurement of this heat value. It is of particular significance that the presence of the water-cooled radiant-heat absorbing surface appears to have no influence on the effectiveness of heat generation. No one has suggested that a higher heat value could be obtained if the burner were placed below the calorimeter

inside a hollow firebrick cylinder so that the calorimeter received heat only by convection. It is more probable that this arrangement would give lower values than the present calorimeter. Since the calorimeter gives substantially 100 per cent of the heat value of the gas, the cooling effect by radiation on the burner flame must be of no significance. One can, therefore, conclude that if a given amount of heat is generated in a furnace by the chemical union of two elements, the boiler efficiency should at least remain the same regardless of whether this heat is absorbed as radiant heat or by convection in the usual manner. There are, however, reasons for believing that the efficiency will be higher when the greater portion of the heat is absorbed as radiant heat.

Effect on Furnace Temperature

In view of the fact that a large amount of heat is absorbed as radiant heat in the boilers and calorimeter previously referred to, it is reasonable to expect that it will have some effect on furnace temperature. Granted that there is a decrease in furnace temperature, it has already been shown that this appears to have no lessening effect on boiler efficiency. It is recognized that heat transfer by convection increases with furnace temperature. The problem before the engineer is, therefore, to decide how much he can sacrifice furnace temperature through highly efficient transfer by radiant heat and still maintain satisfactory transfer by convection in the remainder of the boiler.

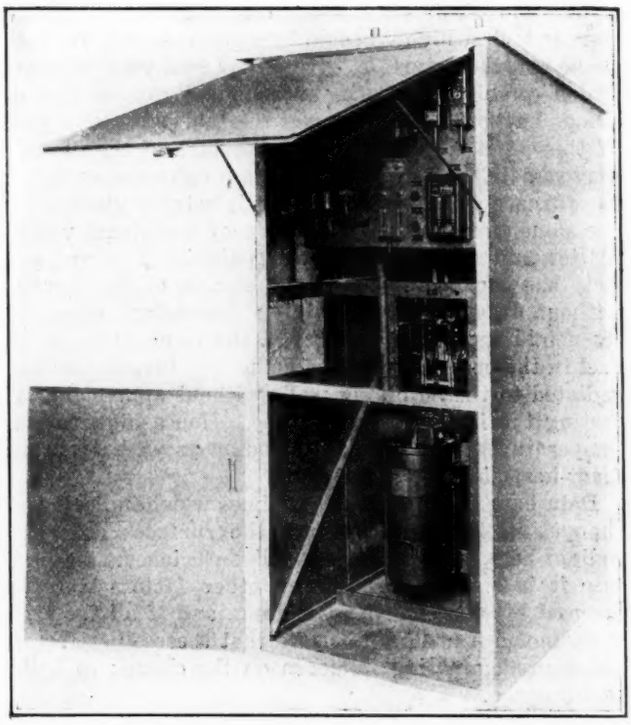
In view of the previous reasoning it is apparent that water-screened areas in powdered-coal furnaces can be greatly increased over present practice with an improvement of boiler efficiency. Higher boiler efficiency would probably be obtained if the whole of the furnace side walls were water-screened. If these screen tubes are placed so that the brick side walls are protected from overheating with the highest possible furnace temperatures, then a minimum amount of excess air may be used. This would result in higher boiler efficiency. It would seem that the large abstraction of radiant heat in the furnace itself would leave less to be absorbed by convection in the boiler proper. Hence the boiler surface may be reduced or, if retained, would have the effect of additional heat-absorbing surface, which would be conducive to still higher boiler efficiency. Finally, with water-cooled furnace walls it will be possible to preheat the air entering the furnace by waste flue gases, thus further increasing boiler efficiency.

This discussion leads to the conclusion that the radiant heat is largely emitted by the outer envelope of the flame, that additional water-tube surface in the furnace side walls can be employed to absorb more radiant heat than at present, and that the protection of such side walls permits the use of less excess air, resulting in improved over-all boiler efficiency.

Where the circulating pump of a condenser is driven by a constant-speed induction motor, it is usually found that there is little saved in power consumption by throttling the inlet or discharge circulating-water valves, consequently in this case, where the supply is adequate, it will be found advisable to use the full quantity at all times. In cases where the circulating pump is driven by a variable-speed motor or turbine, that speed should be used which will give the lowest water rate for the main turbine and auxiliaries as a unit and which may not always be the condition giving the highest vacuum.

Automatic Outdoor Station for Small Power Installations

An automatic outdoor station of moderate capacity has been developed for use on supply light and power circuits in small communities, for service to farms, industrial plants and other small power consumers. The equipment comprises a combination switch, fuse and choke coil mounted on a galvanized structural-steel frame, metering equipment, lightning arrester and automatic reclosing switch. The weatherproof housing contains an automatic oil circuit breaker, watt-hour meter,



SHOWS ARRANGEMENT OF SWITCHING AND METERING EQUIPMENT IN SWITCH HOUSE

reclosing relay, notching relay and overload relays. A set of buses for the low-tension side of the transformers is provided for forming the delta.

The station functions upon the tripping of the oil circuit breaker on overload. After an interval of from five to thirty seconds the reclosing relay operates and recloses the breaker. The breaker will remain closed if the overload has been cleared, but if the overload still exists the breaker will again trip out and, after an interval of from five to fifty seconds, be reclosed by the reclosing relay. Should the overload still exist, the breaker will again be tripped and locked in the open position until reclosed and reset by hand. In most cases a short-circuit or other fault in the line would be cleared by the first tripping of the oil circuit breaker. Continuity of service is assured since the breaker recloses within five to thirty seconds after the occurrence of a fault in the line.

The equipment is built by the General Electric Co. and is for moderate sizes of transformers of from 13,200 to 44,000 volts and up to 600-kva. three-phase capacity. For larger-capacity transformers, up to 3,000-kva. three-phase or when connected to a large capacity network, it is desirable to use an oil circuit breaker in place of fuses on the high-voltage side of the station.

High-Speed Carbon-Dioxide Compressor Installation

By A. R. Stevenson, Jr.*

The air-cooling system recently installed in the Chicago Theater is interesting not only from the fact that it is successful, but also because of some of the electrical and mechanical engineering problems involved. Air for ventilating and cooling various Chicago theaters has in the past been obtained from an old tunnel running beneath the city, but the demands upon this supply were so great that it did not furnish enough for them all. Therefore it was decided, when the ventilation system of the Chicago Theater was being planned, that an artificial cooling system would have to be provided. Carbon-dioxide compressors were selected for the purpose because a leak of carbon dioxide would do no serious damage, whereas if ammonia compressors were used an ammonia leak might have serious effects.

As a result of an engineering study by Milton C. Hartman, consulting engineer, working in conjunction with the engineering department of the General Electric Co., it was decided to speed up the compressors and to use two small cylinders instead of one large one, and to employ direct connected motors. A factor that had more to do than any other with the adoption of the direct motor drive with duplex cylinders, although the specifications called for belt-driven compressors, was that in designing the buildings little attention had been given to arranging a suitable space in the basement for the installation of this machinery, it being necessary to stagger the machines in order to get them in between the columns. The compressors finally decided on were two-cylinder double-acting, 5-in. bore by 16-in. stroke with cranks at 90 deg. These compressors are for operation between 441 lb. suction and 1,058 lb. gage discharge. The motors chosen are 200-hp. 150 r.p.m. 230-volt direct-current with automatic-starter equipments.

Since the current for operating the compressors was to be obtained from the same feeder that supplied the direct-current lights and motion-picture apparatus of tht theater, it introduced the problem of preventing flickering, as it was considered essential that the compressor motors should not cause any flicker of the lights whatever. It was therefore necessary to figure the size of flywheels that would be required to prevent this condition.

The motors have each a WR^2 of 6,600. Assuming an additional flywheel of 65,400, making a total of 72,000 WR^2, a current pulsation of 19½ per cent of normal due to the compressor was calculated. It was finally decided to run separate feeders to each motor from the switchboard. Under this condition the 19½ per cent current pulsation could affect the voltage of the lights only by causing a variation in the drop in the Edison mains from the substation to the theater switchboard. It was impossible to obtain the resistance of the mains in the street, but it was decided that it would be safe to assume that 19½ per cent current pulsation on two 200-hp. motors would not have a serious effect in raising and lowering the voltage of the street mains. This has worked out satisfactorily, as there is no sign of flicker in the lights.

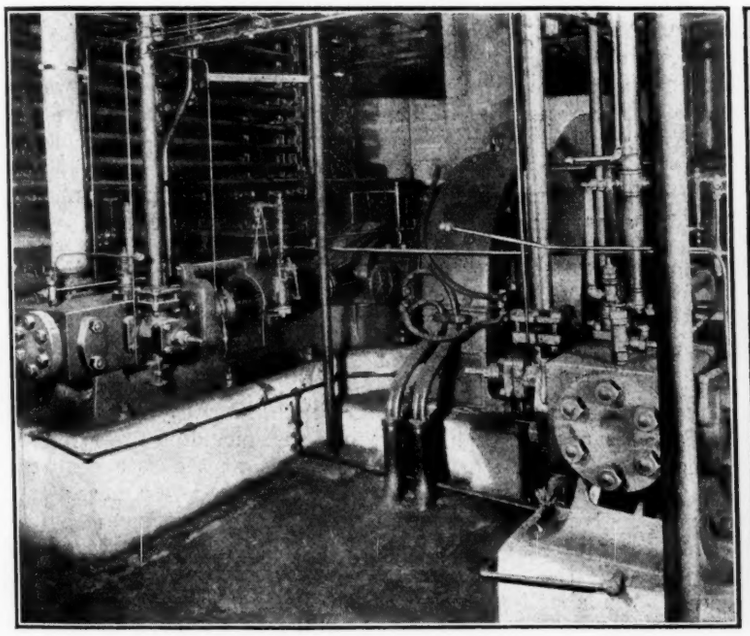


FIG. 1—DIRECT-CURRENT 200-HP. 150-R.P.M. MOTOR DRIVING TWO-CYLINDER 150-TON DOUBLE-ACTING CARBON-DIOXIDE COMPRESSOR

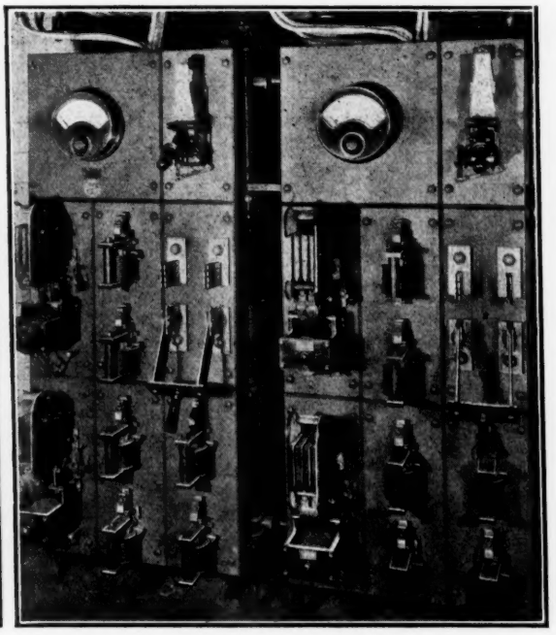


FIG. 2—TWO AUTOMATIC-STARTERS FOR PUSH-BUTTON CONTROL OF 200-HP. DIRECT-CURRENT MOTORS, FIG. 1

*Engineer, Power and Mining Engineering Department, General Electric Company.

Rules for deciding when a cable is sufficiently worn to require renewing are not easily given. A rope working under severe conditions, heavy loading, reverse bends, etc., must be discarded when it reaches a state that under more favorable conditions would allow it to be kept in service several months longer. Experience and judgment give the inspector his cue. An ordinary rule followed by many inspectors is, under average conditions, to condemn a cable when as many as five contiguous wires in a strand are broken. "High strands" are indicated when worn spots appear at equal intervals along the cable.

The Diesel-Powered Central Station

THE question of efficient production of power in large central or superpower stations is being solved by the introduction of high steam pressures, huge turbines, superheaters, reheaters and other modern steam appliances. For large capacities there is no doubt that where water power is not available, the steam turbine will prove the most efficient when all elements of costs are taken into consideration. However, the total number of central stations of capacities large enough to install such turbine plants profitably are limited, and the smaller ones are faced with high production charges by reason of the lower efficiency of the typical small steam units. As an example, while it is possible to produce a kilowatt-hour at an expenditure of 1¼ lb. of coal, the vast majority of central stations consume from two to five times this amount. When coal was available at two dollars a ton, the question of low thermal efficiency was not of great importance since labor and overhead charges were the items that largely determined the cost of power. With present-day high coal prices combined with the high current wages, the position of the small inefficient central stations has not been an enviable one.

TABLE I—OPERATION COSTS IN PLANTS USING NORDBERG DIESELS

Plant	A	B	C	D	E	F
Fuel, cents	$0.344	$0.563	$0.527	$0.764	$0.657	$0.827
Lubricating oil, cents	.066	.021	.036	.040	.035	.089
Labor, cents	.231	.112	.167	.161	.133	.851
Maintenance, cents	.011	.122	.103	.361	.060	.456
Supplies, cents	.004	.007	.002	.015	.004	.062
Water, cents		.023	.021	.033	.014	
K.W. generated	2,242,600	6,079,100	6,230,162	5,817,872	8,171,080	776,104
Cost per kw.-hr., cents	.656	.848	.856	1.374	.903	2.285
Load factor, per cent	51.2	86	69	70	72	36
Average fuel Cost per bbl.	$1.45	$2.52	$2.18	$2.85	$2.35	$2.67

One of the chief advantages of superpower systems is the economies gained by abandoning the small plants and obtaining current by transmission lines. This is feasible in closely congested districts, but entails excessive overhead charges in sections where distances are great and the electric power demand is light.

Under these considerations it is not surprising that a large number of the small central stations, both municipal and corporate, have turned to the oil engine as a means of obtaining not only reduced fuel, but low labor charges as well. The number of oil engines installed in central stations has increased each year until at the present time there are over eleven hundred oil-engine-powered light plants in the United States, although over two thousand plants of less than 1,000 kw. capacity are steam-driven.

The oil engines in these stations are divided between the Diesel and the semi-Diesel engines in terms of number on the basis of 25 and 75 per cent respectively. In horsepower the two types of engines are practically on a parity. The Diesels, being built in large sizes, are preferred for units of over 300 kilowatts.

An example of the great saving made by installing oil engines is the municipal light and water plant at Miami, Okla. Originally, the plant contained reciprocating steam-engine-driven generators, steam-driven water pumps, boilers, etc. Even though the town is situated close to the Kansas and Oklahoma coal fields, making the fuel prices comparatively low, the system was always a burden on the town. Each year an operating deficit was covered by a tax levy.

This deplorable but by no means uncommon situation prompted the town to issue bonds and install a Diesel-powered plant. This original oil-engine installation consisted of a 500-hp. Fulton Diesel direct-connected to a generator. To pump the water, an air lift was installed, while motor-driven centrifugal pumps forced the water from the reservoir into the mains. Since the water-service equipment was motor-driven, it was possible to separate the lighting and water-works accounts, and it was found that the cost of producing energy was as shown in the following table:

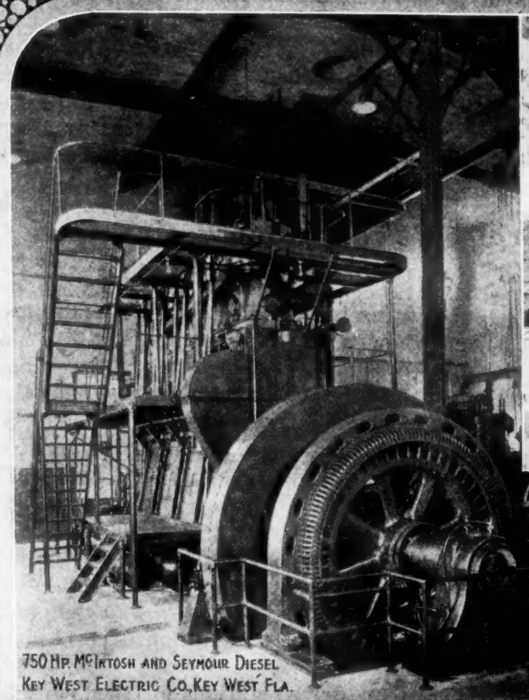
Fuel cost per kilowatt-hour ($2.55 per bbl.)	$0.00483
Labor cost	0.00518
Lubricating oil, etc.	0.00580
Insurance and taxes, 4 per cent	0.00170
Depreciation, 6 per cent	0.00250
Interest, 6 per cent	0.00250
Total cost per kilowatt-hour	$0.02251

This was so much lower than the previous costs in the steam plant that the saving, even including the interest on the old steam-plant bonds, is at the rate of over $25,000 a year. The cost of 2.25c. per kw.-hr. may seem high to executives of large plants, but it must be remembered that the plant capacity (375 kw.) together with the Oklahoma law requiring three shifts, made the labor item greater than the fuel. A second Fulton Diesel was later installed, and the increased output has, by reducing the labor and lubricating oil and overhead charges, brought the cost per kilowatt-hour considerably below the value given. A view of the plant after the installation of the second unit appears in the illustration.

Another plant where the Diesel engine has shown economies impossible with steam units is the Calumet Station of the Chicago Sanitary District. This station was designed to be a stand-by or emergency plant to furnish power to the many sewerage pumps which lift the city sewage from the sewers into the river, and was to operate only when the transmission lines were out of commission. So reliable and economical have the four

TABLE II—OPERATING COSTS, EL CAMPO, TEXAS

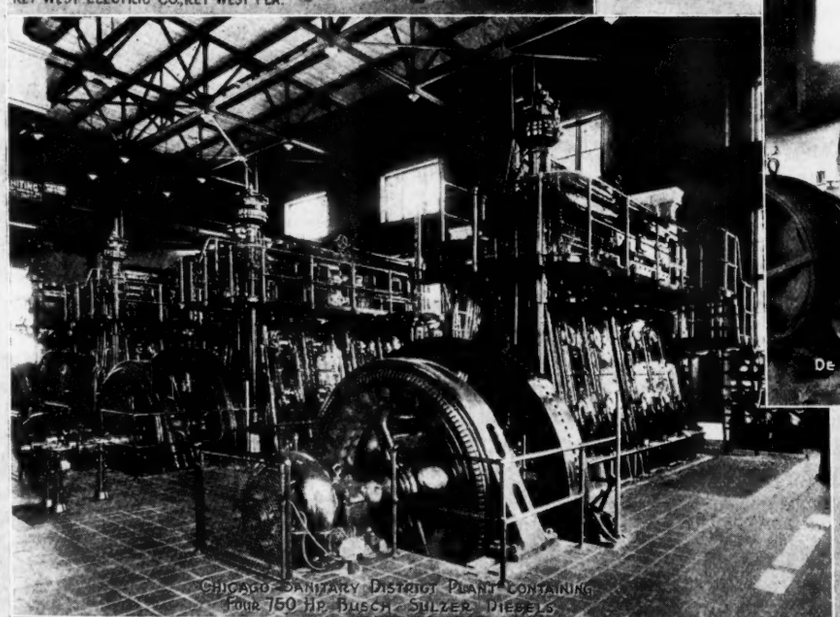
	Kw.-Hr. Generated	Fuel Oil: Barrels Consumed	Fuel Oil: Cost per Bbl.	Total Fuel Cost	Lubricating Oil and Supplies	Attendance	Maintenance	Cost per Kw.-Hr.	Kw.-Hr. per Gal. Fuel Oil
January	70,340	153.7	$4.142	636.62	$188.29	$129.65	$55.25	$0.0143	10.89
February	50,113	120.47	4.143	499.10	148.79	120.47	56.35	0.0164	9.94
March	54,644	137.71	2.984	410.93	141.83	175.00	68.50	0.0146	9.45
April	49,869	136.18	2.287	311.44	206.34	168.30	70.00	0.0151	8.71
May	51,649	133.26	2.287	304.76	303.60	163.00	87.00	0.0166	9.22
June	57,135	131.3	2.122	288.61	131.12	121.00	70.00	0.0107	10.36
July	59,822	143.00	2.122	303.44	92.30	115.00	58.90	0.0095	9.96
August	65,181	121.93	1.746	231.00	153.33	121.00	47.85	0.0084	12.72
September	77,854	171.8	2.12	360.91	207.17	115.06	48.35	0.0094	10.71
October	58,205	136.9	1.86	222.68	141.15	140.00	47.35	0.0095	10.12
November	44,552	107.2	1.85	198.50	156.80	142.75	49.00	0.0123	9.85
December	40,829	113.7	1.85	210.35	104.05	121.25	55.25	0.0120	8.55
Total	680,193	1,607.15		3,978.34	$1,974.77	$1,632.48	$713.80		
Average	56,683	133.93	$2.48	331.53	$164.56	$136.04	$59.48	$0.0122	10.08



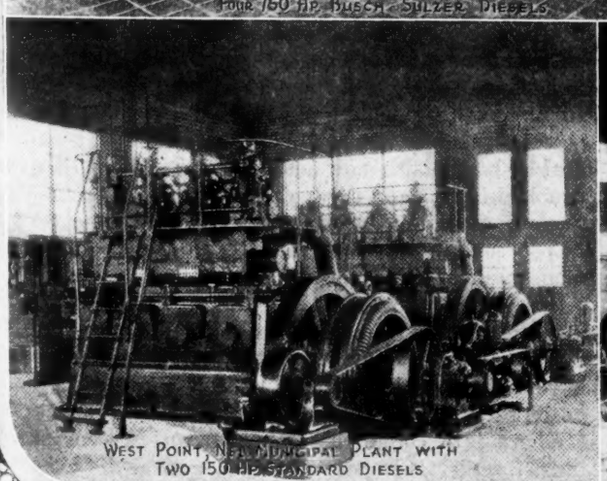
750 Hp. McIntosh and Seymour Diesel
Key West Electric Co., Key West Fla.

Nordberg 550 Hp. Diesels
Municipal Light Plant, Neodesha Kansas

De La Vergne Solid Injection Diesel
Charlottesville Va.



Chicago Sanitary District Plant containing
Four 750 Hp. Busch-Sulzer Diesels.



West Point, Neb. Municipal Plant with
Two 150 Hp. Standard Diesels

Fulton Diesel in Miami, Oklahoma
Municipal Plant.

750-hp. Busch-Sulzer two-stroke-cycle Diesel units proved, that the station is operated continuously, taking care of the sewage pumping and a lighting load. Going into commission a year ago, the plant operates with a capacity factor of from 90 to 110 per cent for 144 hours a week.

The fuel used is for the most part Oklahoma 26-deg. Baumé oil, weighing about 7.47 lb. per gal. and containing some 19,500 B.t.u. per lb. The average fuel consumption per kilowatt-hour is 0.62 lb., or 12,090 B.t.u. The fuel cost of four mills per kilowatt-hour is in marked contrast to the fuel costs of steam plants of like capacity.

West Point, Nebraska, for a number of years was supplied with direct-current for lighting and power by a small corporately owned steam plant consisting of two boilers, a high-speed automatic and a vertical compound single-acting engine. The service rendered was such that the town voted bonds to install a municipal plant. After due consideration two 150-hp. Standard two-stroke-cycle Diesels direct connected to alternating-current generators were purchased. This plant has operated successfully since installation and at a cost per kilowatt-hour much below that possible with a small steam plant.

Neodesha, Kan., has had a municipal plant for years. Originally, gas was used for fuel under boilers, the engines being of the Corliss type. As long as gas was plentiful and cheap, the fuel costs were not excessive, but with the increase in the price of gas, the cost of operation became excessive.

As a solution two 550-hp. Nordberg Diesels were installed, a view of the units being shown in the illustration. These units have operated on an exceedingly heavy oil without any decrease in the reliability of service.

Florida is far removed from the coal fields, and oil has become the standard fuel even for steam plants. The higher efficiency obtained when using the oil in Diesel engines over that in using the oil in steam plants, led the Key West Electric Co. to install Diesels long before this type had been accepted by engineers at large as reliable. For some twelve years the plant used these early American Diesels, but in 1922 the plant capacity was increased by the addition of a 750-hp. McIntosh & Seymour four-stroke cycle crosshead-type Diesel as shown in the illustration.

The airless, or solid-injection, oil engine has been developed during the last four years until it is fully as reliable as the air-injection engine within the range of power to which the former is adapted. A view of a De La Vergne solid-injection engine installed at Charlottesville, Va., appears in the illustration.

Accurate power costs in oil-engine plants are as difficult to obtain as those of steam plants. Taking the average of a large number of plants whose costs are known, it would seem that the determining items are fuel and labor.

In Table I are given cost data for six plants using Nordberg Diesels. Even in plant *E*, with fuel costing over 6c. per gal. and with a load factor of 36 per cent, which causes a high labor charge, the operating cost per kilowatt-hour is only 2.285 cents.

The question of maintenance of a Diesel plant is often raised by those who assume that this cost item is high. In 1915 a 165-hp. Busch-Sulzer Diesel was installed by the Central Service Co., El Campo, Tex. In 1921 this unit operated 98.47 per cent of the time, the actual hours being 8,626. As Table II shows, the maintenance amounted to a total of $713.80, being slightly over one mill per kilowatt-hour.

While it is desirable to have the plant loaded to, say, 80 per cent capacity in order to reduce the overhead and labor costs, the Diesel fuel economy is far more uniform than is that of a steam plant and for that reason is especially suited for plants with a widely fluctuating load.

British Power Station Performance

BY JOHNSTONE TAYLOR

The recent returns by the Electricity Commissioners on fuel consumption in public power stations in Britain cannot be said to show a satisfactory state of affairs, and generally speaking, power users believe that there is considerable room for improvement. The report covers over 500 generating stations, of which 396 are steam driven, 60 operate on producer gas and 52 are worked by oil engines, the remainder covering small plants operated by either water power or waste products.

The steam stations, which of course include the most modern of the large plants, consumed a total of 6,577,587 tons of coal during the twelve months' working under review, giving an average consumption of 3.11 lb. of coal per unit generated.

True, the 396 steam-driven stations included some 352 of comparatively small size, whose average coal consumption is 3¼ lb. per kilowatt-hour. Of the remaining 44, which generate about 64 per cent of the total power, the lowest figure (2.1 lb. per kw.-hr.) is for two plants having an output of over 200,000,000 kw.-hr. per year. Against this there are 26 small stations with an average consumption of over 8½ lb. of coal per kilowatt-hour generated.

Large superpower plants are being erected in various parts of the country, including the new Manchester plant of 105,000-kw. ultimate capacity near completion in Birmingham. This is an interesting plant involving the erection of 42 B. & W. land-type marine boilers supplying steam at 320 lb. and 700 deg., the maximum evaporation of each unit being 42,000 lb. per hour. The boilers are designed for utilizing low-grade fuel.

The turbines are of the Curtis impulse type, the turbo-alternator sets having a capacity of 15,000 kw. each, running at 1,500 r.p.m. and generating 25-cycle current at 5,250 volts. Other stations of a like nature are under consideration in other districts.

British power stations are in a pretty favorable position for generating cheap power. Most of them provide current for tramway operation, giving a good load some two hours before and for several hours after manufacturing establishments are closed.

Those in the manufacturing districts can usually get coal by barge, although admittedly the circulating-water problem is in many cases difficult, calling for the extensive use of cooling towers. The trouble lies not so much in poor operation of the few large units as in the enormous number of small ones.

These, erected mostly about the beginning of the present century, went in for high-speed steam engines (the old Willans was a favorite type), and few of the owners have had the boldness or foresight to scrap them and go in for gas or oil.

There is a congestion of power users near the big towns, while those who prefer the rural districts ordinarily arrange to generate their own power.

Results of Tests on Five Types of Draft Tubes

THESE Tests Were Conducted for the Purpose of Securing a Comparison of Performance Between the Older Forms of Elbow Draft Tubes, a Type of Elbow Draft Tube Recently Developed and the New Symmetrical Types of Draft Tubes.

ALTHOUGH the use of waterwheels to supply man's needs as a source of power is so old as to be lost in antiquity, it is only within comparatively recent years that their design has been understood. Previous to this they were made largely by cut-and-try methods, consequently no great progress could be expected toward producing efficient wheels and settings. The setting is now recognized as being equal in importance with the wheel itself. In 1900 the largest wheel installed was of 5,000-hp. capacity and had an efficiency of about 63 per cent at 50 per cent rated power and 80 per cent at 100 per cent, with the efficiency curve inclining sharply upward, indicating that the maximum would be obtained at considerably above the rated load of the machine, a point where the turbine was not intended to operate.

The remarkable improvement in the hydraulic turbine following 1900 is shown by the 37,500-hp. units installed by the Niagara Falls Power Co. in 1919 and 1920. These had an efficiency of 90 per cent at about 50 per cent and at full load, with a maximum efficiency of 93 per cent between 70 and 85 per cent load. Bringing the turbine up to its present high state of perfection is not due to runner design alone, but also to giving careful attention to all parts of the setting.

Symmetrical Types of Draft Tubes

With turbines of even moderate sizes the cost of excavation necessary to the efficient use of an ordinary straight-type draft tube led to the adoption of the bent type, and although the use of these tubes materially reduced the cost of the installation, they were found to be seriously defective in operation in many cases. The great size of modern turbines and the effect of only a fraction of one per cent gain in efficiency on the output of the unit from a given amount of water led to careful study of the development of symmetrical types of draft tubes that would regain both the axial and tangential components of flow, and do so without excessive excavation costs for their installation.

One of these symmetrical types is the hydraucone regainer developed by William M. White, manager, Hydraulic Department, Allis-Chalmers Co. Another type is the so-called spreading draft tube developed by Lewis F. Moody, consulting engineer, I. P. Morris Department, William Cramp & Sons Ship and Engine Building Co. In the latter the water passage is an annular space between an outer flaring wall and an inner core, in which the axial components of flow are gradually turned in the radial direction and at the same time are continuously reduced in magnitude.

When the designs were laid down for the government hydro-electric development at Muscle Shoals, a draft tube of the Moody spreading type was adopted from this particular installation by Hugh L. Cooper & Co., consulting engineers on this project. This type at that time was shown by tests on models to be the most economical from both an engineering and a financial viewpoint. Since then the development in draft-tube design has brought out other types that merited consideration, since under test for certain conditions they apparently showed the possibilities of a reduction in cost of construction sufficient to offset the difference in efficiency, as compared with the type adopted for the first four units to be installed at Muscle Shoals. This led to a series of tests being ordered by Major General Lansing H. Beach, Chief of Engineers, U. S. Army, to be conducted on various types of draft tubes in the I. P. Morris laboratory for the War Department, under the supervision of Hugh L. Cooper & Co., consulting engineers. The purpose of the test was to secure a comparison of performance between types of bent tubes of simple design and comparatively easy and cheap to construct and some of the more recent types which are highly efficient but involve expensive reinforced-concrete construction.

Model of High Specific-Speed Runner Tested

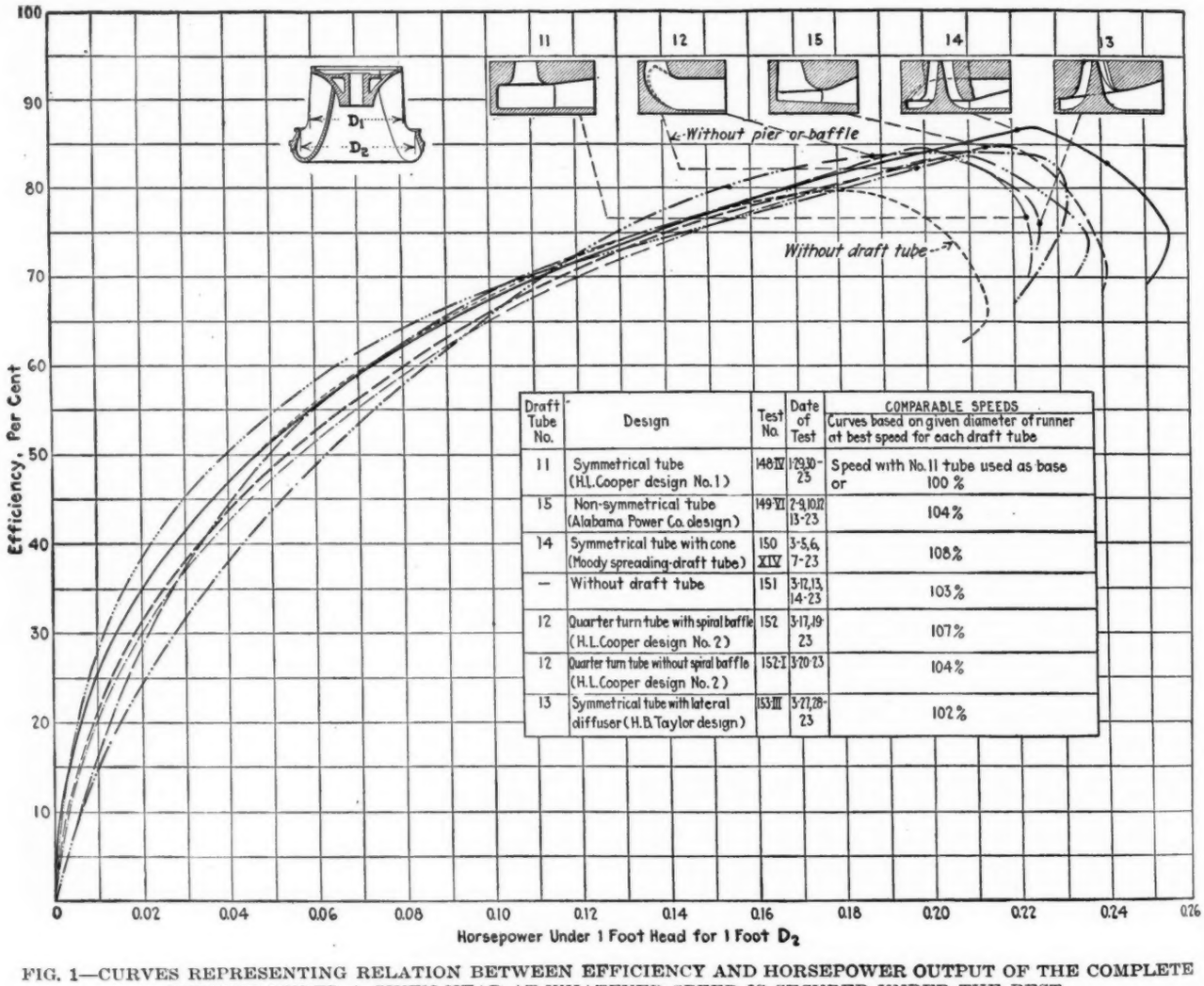
Tests were made of a model of a complete turbine equipped with a high specific-speed runner of the usual mixed flow, or so-called Francis type, similar to the 35,600-hp. units to be installed at Muscle Shoals, and with draft tubes geometrically similar to those that would be used in this installation. All parts of the turbine, testing flume and testing equipment remained the same in each test with the single exception of the type of draft tube provided, and each tube was designed to come within the same space restrictions. Tubes of five types were tested. These are shown on the curve sheets, Figs. 1 and 2, and in Figs. 3 to 6. No attempt was made to prove that one type was more efficient than another except for the condition in question. During the tests Hugh L. Cooper & Co., and the War Department were represented by I. A. Winter, of the Alabama Power Co.; R. A. Schroeder, A. H. Reeves and A. C. Bruce, of Hugh L. Cooper & Co. Representing the I. P. Morris Department of the Cramp Co. were C. B. Spellman, test engineer, and R. I. Todd.

Fig. 3 shows sections through a symmetrical type of tube indicated at No. 11 on the curves. As indicated by section *AA*, this tube had a vertical baffle that extended well up into the neck of the tube, otherwise the construction was similar to a short conical type with a vertical pier in the center of the horizontal discharge section. As might be expected, this tube showed up poorly in efficiency, probably owing to the short length of the tube and the baffle directly under the discharge from the turbine, causing turbulence which prevented the water from flowing readily from the tube.

In Fig. 4 are given sections of a bent tube with a baffle in it. This baffle might be considered as an extension of the vertical pier in the horizontal section of the tube, which is given a 90-deg. turn as it approaches the bottom of the turbine's casing and extends up to within about three inches of the runner. At this point it is reduced to a thin edge at right angles to the pier in the horizontal section of the tube. This type of tube with its 90-deg. spiral baffle showed considerably

better results than design No. 11, between 50 per cent load and normal rated power of the turbine. However, below 50 per cent load the efficiency fell off rapidly and showed a lower efficiency at light loads than any of the other types tested. Tests were made on this tube with the spiral baffle and the pier removed, which made the tube similar to the ordinary bent type. Under this condition from about 60 per cent full load to normal rated capacity the efficiency is lower than with the baffle. Below 60 per cent load the efficiency holds up better than with the baffles and from 50 per cent load down not so great. In fact, the results of the Worcester tests led to Hugh L. Cooper & Co.'s carrying on the tests at the direction of the War Department to make sure that the advance in draft-tube design had not produced a type more economical than that available when the Muscle Shoals project was first decided upon.

Two sectional views of a model of the type of spreading tubes to be used at Muscle Shoals are shown in Fig. 6. Between 40 per cent and 100 per cent load, or throughout the usual operating range, this tube shows better turbine efficiency, does this with the turbine oper-



Draft Tube No.	Design	Test No.	Date of Test	COMPARABLE SPEEDS Curves based on given diameter of runner at best speed for each draft tube
11	Symmetrical tube (H.L.Cooper design No.1)	148 IV	1-29,30-23	Speed with No.11 tube used as base or 100 %
15	Non-symmetrical tube (Alabama Power Co. design)	149 VI	2-9,10,12 13-23	104 %
14	Symmetrical tube with cone (Moody spreading-draft tube)	150 XIV	3-5,6, 7-23	108 %
—	Without draft tube	151	3-12,13, 14-23	103 %
12	Quarter turn tube with spiral baffle (H.L.Cooper design No. 2)	152	3-17,19-23	107 %
12	Quarter turn tube without spiral baffle (H.L.Cooper design No. 2)	152-I	3-20-23	104 %
13	Symmetrical tube with lateral diffuser (H.B.Taylor design)	153 III	3-27,28-23	102 %

FIG. 1—CURVES REPRESENTING RELATION BETWEEN EFFICIENCY AND HORSEPOWER OUTPUT OF THE COMPLETE TURBINE UNDER A GIVEN HEAD AT WHATEVER SPEED IS SECURED UNDER THE BEST CONDITIONS WITH EACH DRAFT TUBE

These curves and those in Fig. 2 were approved and signed by H. Birchard Taylor, vice-president, Cramp Co.; Hugh L. Cooper; and Major General Lansing H. Beach, Chief of Engineers, U. S. Army. The cross-section of the runner shown on this figure is not the Muscle Shoals, but has about the same specific speed and is shown only to indicate the D_2 dimension.

shows a better efficiency than any of the other types tested.

Design No. 15 is of a type similar to that developed for the Mitchell Dam project of the Alabama Power Co. and is shown in section in Fig. 5. The curve of this type falls in an intermediate position in regard to those of the other types. Although, in these tests this tube shows a lower turbine efficiency by about 2 per cent than model No. 14, which is the Moody spreading type, on a prior test made at Worcester, Mass., on a tube of a design similar to No. 15, and under conditions similar to those at Mitchell Dam the difference in efficiency was ating at a higher speed, and the turbine develops from 6 to 14 per cent more power than with any of the other types.

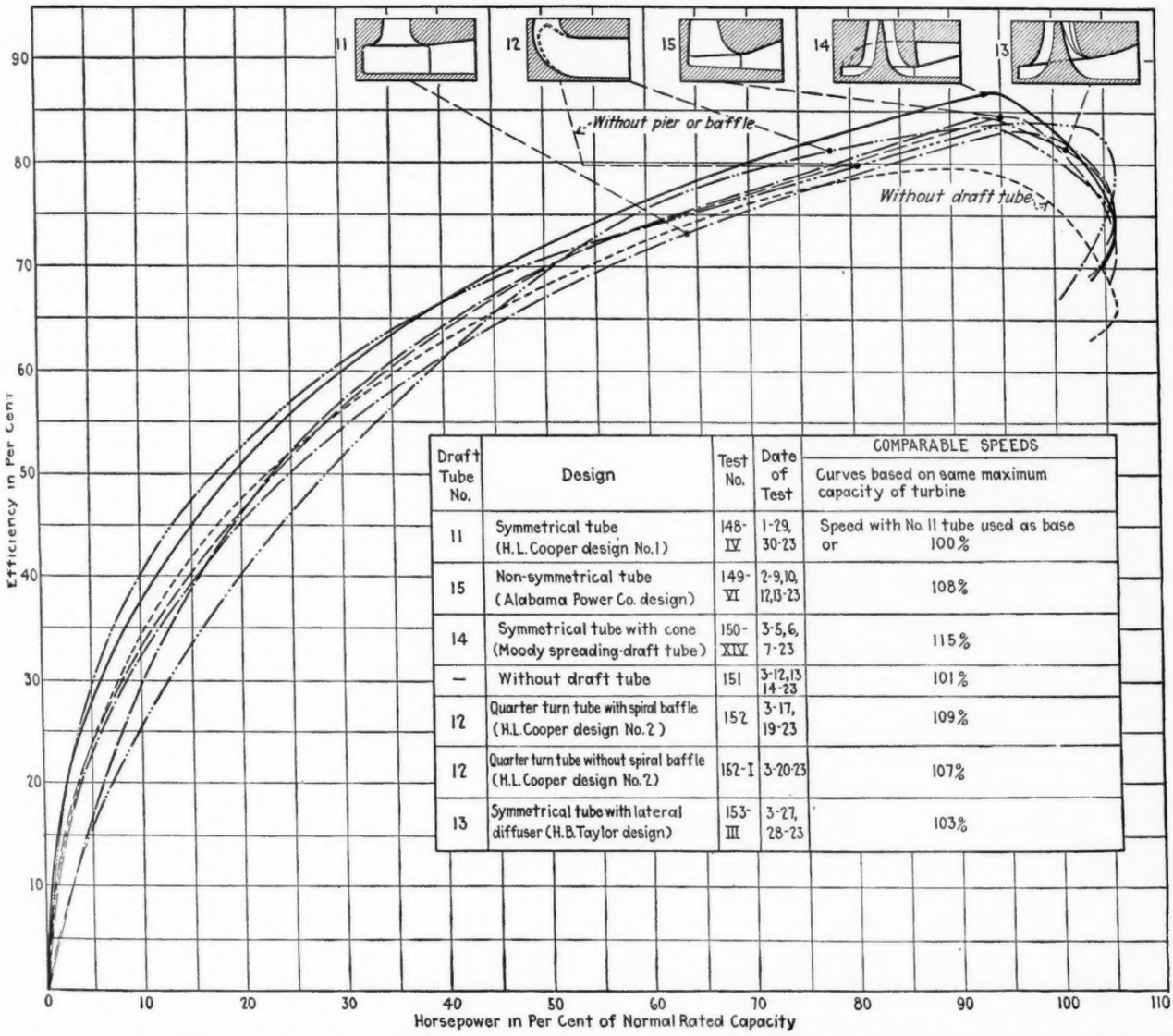
A test was also made on a model tube having a lateral diffuser as shown at 13, Figs. 1 and 2. This arrangement gave an efficiency inferior to some of the other models. Each curve represents the run secured under the best conditions for that tube.

Referring to Fig. 1, the curves represent the relation between the total efficiency and the horsepower output of the complete turbine under a given head at whatever speed is secured under the best conditions with each

draft tube. The curve shown in dotted lines represents the performance of the turbine without any draft tube. In this test the runner discharge passed into a wide chamber, the discharge from this chamber being submerged below the tailwater surface so that there was no loss of static head on the turbine. The difference in turbine efficiency of 7 per cent and over 19 per cent in power capacity shows clearly the effects of equipping the turbine with an efficient type of draft tube.

The results, Fig. 2, have been plotted to show the efficiencies at various percentages of power which would operating range; namely, from 40 to 99 per cent of rated full load.

It might be mentioned that draft tube No. 14 was tested both with a high cone, as indicated on the curves, and with a somewhat lower cone, and the comparison resulted in favor of the high cone, although the difference was not great in this case. The advantage, however, of the higher cone in most installations is that it results in higher efficiency and also produces quieter and steadier conditions of flow. In the ordinary types of draft tube the center is occupied by turbulent water



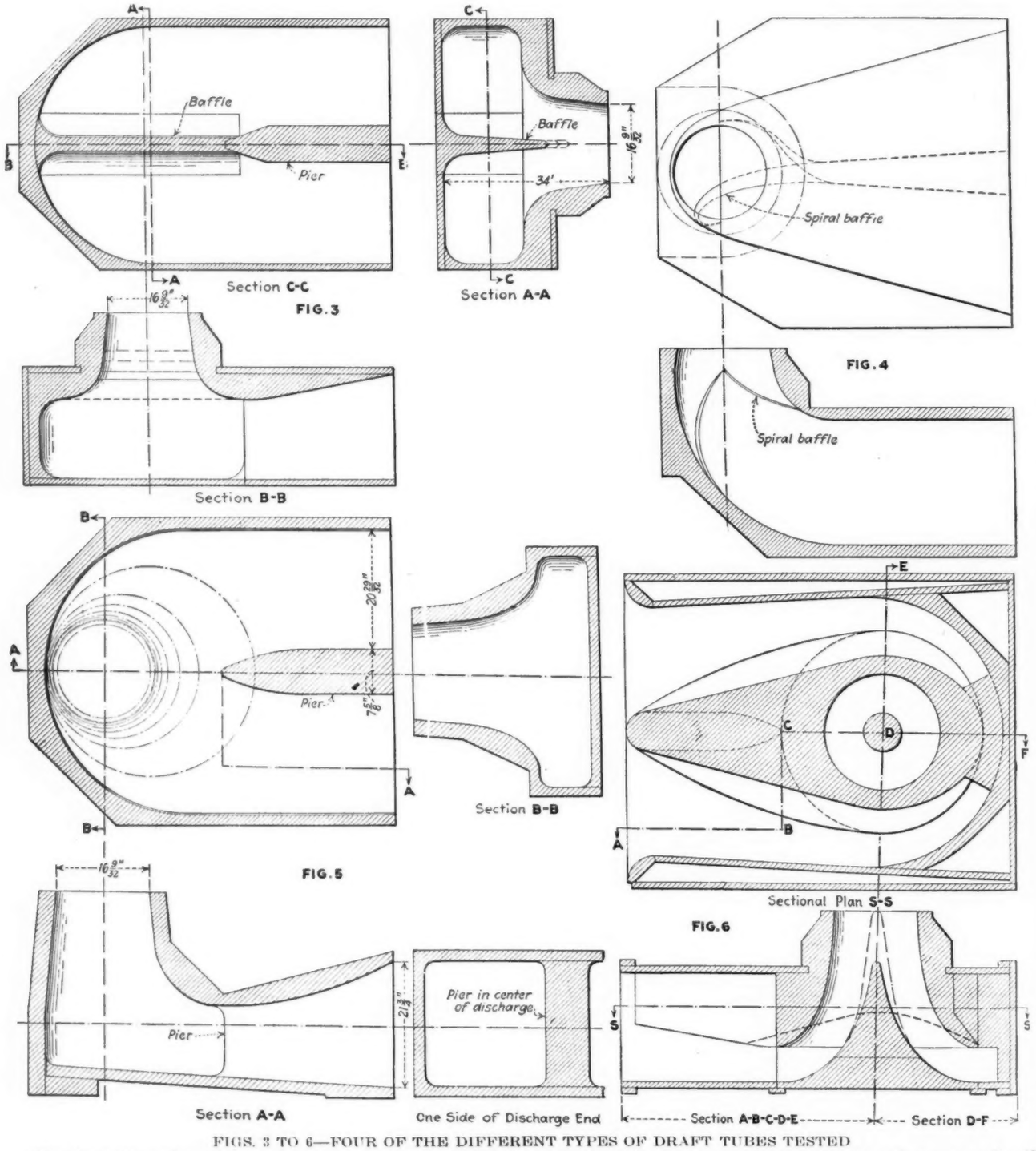
Draft Tube No.	Design	Test No.	Date of Test	COMPARABLE SPEEDS Curves based on same maximum capacity of turbine
11	Symmetrical tube (H.L. Cooper design No.1)	148-IV	1-29, 30-23	Speed with No. 11 tube used as base or 100%
15	Non-symmetrical tube (Alabama Power Co. design)	149-VI	2-9,10, 12,13-23	108%
14	Symmetrical tube with cone (Moody spreading-draft tube)	150-XIV	3-5,6, 7-23	115%
—	Without draft tube	151	3-12,13 14-23	101%
12	Quarter turn tube with spiral baffle (H.L. Cooper design No.2)	152	3-17, 19-23	109%
12	Quarter turn tube without spiral baffle (H.L. Cooper design No.2)	152-I	3-20-23	107%
13	Symmetrical tube with lateral diffuser (H.B. Taylor design)	153-III	3-27, 28-23	103%

FIG. 2—CURVES SHOWING THE EFFICIENCY AT VARIOUS PERCENTAGES OF THE POWER WHICH WOULD BE THE RATED OUTPUT OF THE TURBINE WHEN EQUIPPED WITH EACH OF THE DRAFT TUBES

be the rated output of the turbine when equipped with each draft tube. These curves therefore give a comparison of part-load performances without regard to what the actual full-load output may be and without regard to the difference in speed of the turbine. The relative speeds for both sets of curves are given in the table on each sheet. These curves show that with a turbine designed for a suitable power output and a suitable speed, the spreading draft tube would exceed the others not only with respect to peak efficiency, but also for efficiencies at powers throughout the ordinary not partaking of the general stream-line flow, and under extreme conditions there may be a cavity filled with air or vapor at this point, a condition which is removed by filling this region with a solid core. This arrangement not only eliminates certain internal conditions, but also, through the removal of inertia effects in the center of the draft tube, prevents them from being transmitted to the penstock, which in some installations has resulted in water hammer or surging involving pressure rises as high as 25 to 35 lb. per sq.in. The 70,000-hp. units being built for the Niagara Falls Power

Co. will be equipped with draft tubes with the cone extending to the runner. The same remark applies to the new 58,000-hp. unit No. 6 for the Queenston station of the Hydro-Electric Power Commission of Ontario. The use of a cone even of moderate height in the draft tube has shown a marked effect in producing steady conditions and in preventing inertia effects, and apparently the logical procedure is to run the cone to the runner.

These tests represent a contribution to a phase of turbine design which in the past has been neglected. When we consider the effort that has been expended on the part of the hydro-electric industry to secure increases in turbine efficiencies of fractions of one per cent by improvements in runner design, it is manifest that improvement in the efficiency of the turbine as a whole by improving the draft tube is equally important. The draft tube of a turbine must be designed to take care of a complex condition of flow, and each installation requires special treatment and study, and it cannot be said that results arrived at in one condition are applicable to another without giving the particular flow involved in the draft tube due consideration.



FIGS. 3 TO 6—FOUR OF THE DIFFERENT TYPES OF DRAFT TUBES TESTED

Fig. 3—Sections through a symmetrical type of tube indicated as No. 11 on the curves. Fig. 4—Sections of a bent draft tube with a spiral baffle shown as No. 12 on the curves. Fig. 5—Sections through new type of bent draft tube and shown as No. 15 on the curves. Fig. 6—Sections through spreading type of draft tube indicated as No. 14 on the curves

EDITORIALS

F. R. LOW, EDITOR

In the New Stations

THE last twelve months has seen greater advances in power-plant practice probably than any like period in the past. This is especially noticeable because of the number of large stations now under construction and the boldness with which many of the designers have set out to secure increased economy, often through the adoption of several innovations at once. Reference to the *Supplement* in this issue will afford opportunity to compare some of the high points of these plants.

Of special note are the greater steam pressures and temperatures, particularly the former. While a few of these stations reflect conservatism in this respect, the majority will employ pressures from 300 to 350 pounds; three will go to 400 and two to 550 pounds at the turbines. Nine will operate at 700 degrees or above. Two of the stations listed will make experimental installations at 1,200 pounds, and two others are reported to be making similar plans.

Coincident with the higher pressures has come the adoption in some cases of reheating between the high- and low-pressure elements of the turbine. This, of course, is intended to offset the decreased thermal efficiency of the turbine that would otherwise result with increased pressures due to wetter steam in the lower stages. One of the first plants to employ reheating was the North Tees station in England. It will be recalled that much secrecy has surrounded this plant since it was placed in operation, and it has been sometimes hinted that the reheating was responsible for some of the early difficulties. Whether this be true or not, it is likely that the newer installations will profit by the experience at North Tees. It is significant that the plants employing reheating will operate under practically base load conditions, which tends to simplify the problem of superheat. The tendency is toward larger boilers to keep pace with the size of turbines and to keep the number of boilers per generating unit at a minimum.

Economizers appear to be gaining favor again, and even those plants that have not installed them have in most cases made provision for their installation later if desired.

Electrically driven auxiliaries have largely supplanted the steam driven except for emergency service, although a few plants are installing both.

Stage bleeding as the major source of feed-water heating seems to have become the accepted practice in most cases, the house turbine being employed chiefly as a stand-by unit floating on the line. In one plant the auxiliary bus is served by an independent generator on the shaft of the main unit.

Other points toward which attention may be directed are the increasing use of evaporators and of pulverized coal. Following upon the results at Lakeside, the first large central station to employ pulverized coal exclusively, came the announcement that it would be burned at Cahokia. Since then it has been adopted for several stations now being laid down and for individual or groups of boilers in a number of existing stations.

As a result of all these innovations the next two or three years should afford a golden opportunity for experience among the operating staffs.

De-Superheaters

THE problem of de-superheating steam is a new one which has been brought to the front by the use of increasingly high pressures and superheats. In many cases the exhaust steam from non-condensing auxiliaries is highly superheated when the throttle pressure and temperature are high. At light loads the superheat in the exhaust generally increases over that at full load, and it may become so great that special care must be taken to deal with it.

In one of the newer power plants all auxiliary turbines have steel casings and the exhaust lines to the heater are also all-steel, as the temperatures usually are over 500 degrees F. The leak-off of the high-pressure gland of impulse turbines may also be highly superheated, and may in some cases be 600 deg. F. in temperature. In some cases the steam bled from turbines to heat feed water will be superheated. There are many cases where it is desirable to remove the superheat before admitting this exhaust steam to heaters or to the low-pressure stages of the main turbine. This is particularly so where closed heaters are used, for otherwise the heating surface will have to be greatly increased on account of the low coefficient of heat transfer of superheated steam.

How can this superheat be best removed? One can assume that several of the washers used in the gas industry to remove tar, etc., could be used for this purpose. Their bulk is great and the pressure drop through them is large. Hence, it does not seem feasible to use them with this exhaust steam. However, the methods used might be applied to steam in some modified design. Attempts have been made to remove the superheat by placing water sprays in the pipe line. If these sprays are to be effective, the water must be practically atomized. Such spray nozzles are hard to keep in adjustment owing to temperature changes and to other causes. Rain-drop effects seem to be incapable of procuring the desired results as the droplets are too large.

Another plan based on surface cooling is to place in the steam line a basket filled with monel-metal cuttings or sections of small brass or monel tubes and to allow condensate to flow over this basket while the superheated steam passes through the metal contents. The large contact surfaces exposed to the baffled steam seems to be particularly effective in removing superheat. The pressure drop will, however, be large. Little development work has been done on de-superheaters although it is evident that this is needed, as they must be more widely used with the increasingly high steam temperatures now in use.

Over the Top of the Entropy Diagram

THE temperature-entropy diagram has long been a sort of holy mountain for engineers. They have explored its lower slopes on both sides and made frequent practical application of the knowledge thus obtained. The upper slopes and rounding top have remained mysterious regions of little more than poetic interest. What did the practical engineer care about the properties of steam at 1,000 pounds pressure, to say nothing of 3,200 pounds!

All this is rapidly changing. First, we hear of steam generation at 500 pounds pressure, then at 900, 1,200 and 1,500 pounds in rapid succession. Now 3,200 pounds is proposed in all seriousness, and one of the largest British manufacturing concerns, the English Electric Company, is backing the construction of a 1,000-kilowatt experimental plant wherein steam will be generated at this pressure.

Whatever the best pressure may ultimately prove to be, the time is ripe for a systematic study of the theoretical and practical possibilities of plants operating at various pressures up to 3,200 pounds. Something has been accomplished along this line, but much more remains to be done. Even if the investigation is confined to the theoretical thermal efficiency, there are many variables to be considered. The most important of these are: Initial pressure, initial temperature, exhaust pressure, number of reheating stages, reheating temperature at each stage, number of bleeding stages (for feed-water heating), pressure at each bleeding stage.

Taking only four different values of each of these seven variables, there are many thousand different combinations for which the theoretical efficiency would have to be computed. It might take several months to figure these, but the expense of making such an extensive study would be negligible in comparison with the cost of a single power plant of moderate size. It is to be hoped that some engineering school or research institution will see fit to make such a study on a comprehensive scale and broaden it, if possible, by introducing the more important practical factors.

The House Turbine A Compromise

WHERE the exhaust is utilized in heating processes, a kilowatt-hour can be produced on an expenditure of about forty-five hundred heat units. The more heat that can be worked out of the steam before it goes to the heater, the greater the power that can be produced from this steam. For this reason a higher station efficiency will be obtained by bleeding the main turbine for feed-water heating and driving all auxiliaries electrically from the main bus than when steam-driven auxiliaries are used and the exhaust used for feed-water heating. Steam bled from the main turbine at ten pounds gage may be saturated or slightly wet, where the exhaust from auxiliary turbines may be highly superheated, cases being on record where the superheat was higher in the exhaust than in the live steam. In the former case more than double the amount of power may be produced on forty-five hundred heat units per kilowatt-hour than with the latter method, consequently the over-all station efficiency is higher with the former.

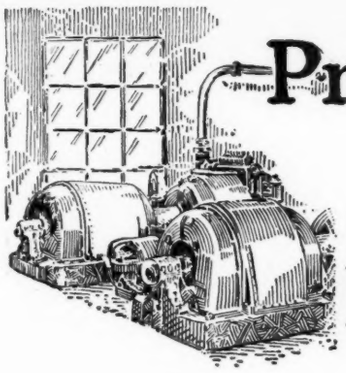
The most serious objection to driving all auxiliaries electrically and bleeding the main turbines for feed-water heating, has been the question of reliability, Should the station go dead, serious difficulties might be experienced in getting started again. A compromise on this method was the introduction of the house turbine. Although this arrangement has been used in a number of important stations, it has been at a sacrifice in economy from that obtainable by supplying auxiliary power from the main generators and bleeding the turbines for feed-water heating.

The recently proposed auxiliary generator for supplying power to the electrically driven auxiliaries seems to possess advantages that would mark the passing of the house turbine except probably as an auxiliary-power standby. In this arrangement a generator of sufficient capacity to supply power to the auxiliaries of the main unit is coupled directly to the main generator shaft. This makes each main unit practically self-contained, without taking auxiliary power from the main busbars. Now that bleeding the main turbine at a number of stages for feed-water heating is coming into practice, this method of supplying power has added advantages. The auxiliary generator should not increase the electrical complications of the station and may result in simplifying the steam connections to a certain extent. In the latter the complications of the house turbine may be eliminated and in their place the connections for bleeding the main turbine introduced. How complicated these will be depends upon how many bleeding connections are used. Connecting the auxiliary generator to the end of the main generator shaft will increase the length of the unit, but this should not involve any serious objections. For a number of years engineers have been looking for some economical method that would allow obtaining the two per cent or more gain in thermal efficiency obtainable by bleeding the main turbine for feed-water heating, without jeopardizing the reliability of the plant, and this seems to be available now in the use of the auxiliary generator directly connected to the main unit.

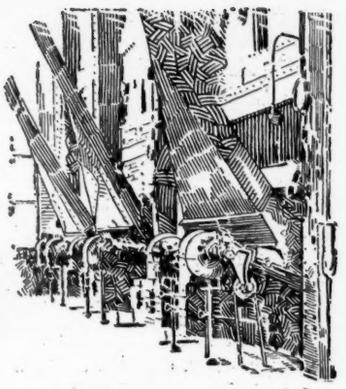
Radiant Heat

PRESENT operating practice, the advent of pulverized fuel and the strife for increased efficiency with decreased furnace maintenance, are responsible for the study now being given to radiant heat by a number of well-known designing engineers. It would not be surprising if this should result in radical changes in furnace design in the near future. That the influence of radiant heat has long been recognized, although often neglected, is apparent by reference to the writings of D. K. Clark, who has in his classic on "The Steam Engine," published in 1890, referred to extensive experiments by Hick, Graham, Wood and others as early as 1840 and 1858, which indicated that one square foot of radiant-heat absorbing surface was equivalent to several square feet of heat transmission by conduction and convection.

The tests on internally fired marine boilers cited by Professor Christie in his article on "The Influence of Radiant Heat on Furnace Design," in this issue, bear out the contentions of these early investigators, and point to the desirability of maximum tube surface exposed to the fire. The promise of decreased refractory temperatures accompanied by lessened necessity for excess air is worth striving for, and the subject is one that invites the fullest discussion.



Practical Ideas *from* Practical Men



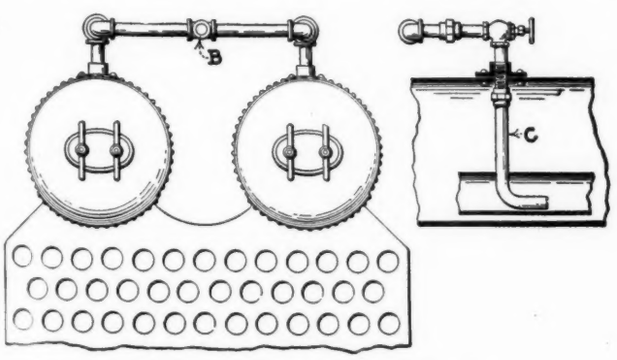
Steam in Feed Pipe Caused Serious Water Hammer

Some time ago I had an interesting experience while employed by a contracting company as chief engineer in charge of two large water-tube boilers, three turbines and their auxiliaries, until the installation was completed and accepted by the company.

When I took charge, steam was on the boilers and a distinct water hammer was perceptible, sometimes much more distinct than at others. After an examination it was evident that the hammer was in the feed-water line, which fed down through the top of the steam drums into the skimmers, as shown in the illustration. This water hammer continued severely until the cast tee *B* cracked and opened up on the side of the outlet, holding only on the opposite side. One of the angle valves could not be shut off because it was off the stem.

As it was absolutely necessary that steps be taken to prevent further fracture of the tee until the pressure could be lowered on a boiler, a heavy C-clamp was obtained from the toolroom and put on the tee. I then cut out the boiler, checked the fire and lowered the steam pressures as quickly as possible. As soon as the pressure was off the boiler, the cast-iron tee was replaced by a steel one, but the next night the same thing occurred.

We then concluded that the trouble was due to a leak in the feed pipe inside the drum, allowing steam to



ARRANGEMENT OF FEED PIPE AND SKIMMER CONNECTIONS

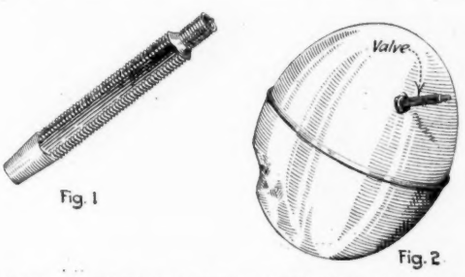
enter the pipe above the surface of the water. On the following Sunday we cooled down the boiler, took out the manhole plate and found that the curved piece of pipe marked *C* had become disconnected. After we had replaced the pipe and put the boiler back in commission, the water hammer ceased altogether.

Detroit, Mich. WALTER MIDDLEDITCH.

Straightening Copper Floats with the Aid of Air Pressure

A method that I have used for straightening copper floats may be of interest to other readers of *Power*.

First, secure a valve from a discarded automobile tube and grind as shown in Fig. 1. Next drill the float and solder the valve in as shown in Fig. 2. Then, by using a tire pump, put sufficient pressure in the float



FIGS. 1 AND 2—TIRE VALVE IS GROUND AND SOLDEREL INTO FLOAT

to bulge out the largest bends. Now with a light hammer tap around the edges of the small bends, gradually working to the center. In this way the float will almost attain its original shape, bringing out even the smallest bends. Finally, melt out the valve and solder up the drill hole and the float is ready for use again.

Bent ice-can filler floats cause the filler to cut off at different places, resulting in long and short blocks of ice. I have used the method outlined on a large number of floats and obtained good results. R. A. HALL.

Macon, Ga.

Power-Plant Repairs

It is often difficult to decide how much or little of the necessary repairs should be done on the spot or sent out. Sometimes this is automatically arranged by the plant being insured for upkeep, while in other cases the owners have interests in other works specially equipped for repairs, and it is then a case of "send everything along," however trivial or important. In cases of this sort the engineer in charge is heavily handicapped and often prevented in various ways from avoiding breakdowns, while, when they do occur, more time than necessary is lost in getting restarted, causing a considerable loss of output.

Competition is often keen, and plants have to run on the smallest margin of profit. Stoppages from any cause whatever are usually expensive, and the plant or firm that can afford to keep up its own repair gang is

going to be in the best position. It is, of course, often said that a firm with a refrigerating plant or the like that puts in machine tools is "butting" into other business besides making its own products, but this is, I think, a narrow view of the matter and does not recognize the importance and urgency of plant repairs. Apart from these points a small amount spent in equipment will, I am sure, reduce the repair bills to such an extent that they will soon pay for themselves.

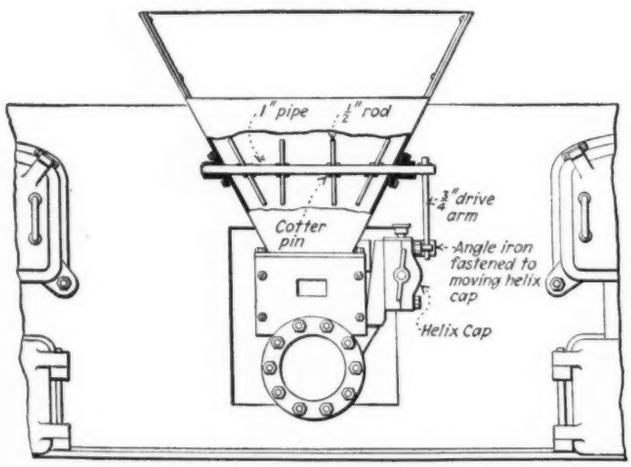
Talking this matter over a few days ago with the manager of a large plant, he informed me that the installation of a lathe, drill press and shaper in the plant had brought down his maintenance costs to less than pre-war, despite today's high prices. This is partly accounted for by the attitude of the men themselves, who find the time occupied in "standing by" passes much more pleasantly than when there is nothing to do. This, of course, is often looked upon as dangerous, but, as this manager pointed out, it is so only when the men are compelled to carry on two jobs. Most failures in a plant are first detected by the ears, and the trained attendant can at once recognize the slightest change of sound even if he is busy with other matters, and so long as the men understand what is their first duty and a bonus is given them "on output" or for "no stoppages," it will pay. Spare parts can be got ready at odd times, castings can be bought partly machined or in the rough much cheaper than finished, and most important of all, the plant has a much better chance of running all the time.

The man in charge of a plant must be ever on the alert, waging a continual war against breakdowns; and just as an army is handicapped without adequate appliances, so is the plant manager without tools and spare parts. F. P. TERRY.

Belfast, Ireland.

Coal Agitator Applied to Single-Retort Stoker

The illustration shows a simple arrangement we have made to agitate the coal in the hoppers of our stokers. Previous to attaching this agitator, it was necessary



AGITATOR IS OPERATED FROM MOVING HELIX CAP

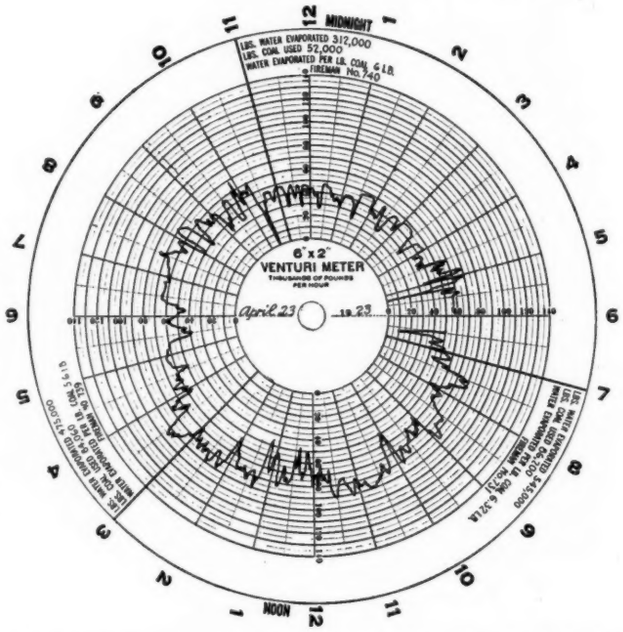
for the fireman to stand continuously at the stokers and poke the coal to get it to feed, especially in the spring of the year when the coal is wet. This arrangement has done away entirely with this trouble.

It can be readily made with a piece of 1-in. pipe and a few pieces of round rod, with the exception of the castings on the side of the hoppers, which can usually be purchased from a local foundry. R. T. POWERS.

St. Paul, Minn.

Convenient Arrangement of Feed-Water Meter Chart

The chart shown herewith, which we had especially printed for our venturi meter, may be of interest to readers of *Power*. The meter is installed on our boiler-feed line for indicating and recording the amount of



SPACE IS PROVIDED ON THE CHART FOR RECORDING ESSENTIAL BOILER-ROOM RESULTS

water fed to the boilers. The coal is also weighed by a weighing larry. The evaporation per pound of coal is figured out, and the fireman's record is kept for each shift.

The chart is divided into three eight-hour shifts, and space is provided to show the pounds of coal used, pounds of water evaporated, the evaporation per pound of coal and the fireman's number.

It will be noticed on the reproduction of the chart shown in the illustration, that the space used for the record is not usually traversed by the pen of the instrument. For meters where the pen travels close to the outer circle, space near the inner circle or any vacant space can be used to enter the desired information. We feel that better average results are obtained by the use of the charts as shown, because each fireman knows that his record is carefully kept and the chart, which is always in full view of the boiler-room force, is a constant reminder that results are required by each individual.

The information is entered on the chart by the boiler-room engineer and delivered to the chief engineer's office, where it is checked over and filed. The form is especially convenient for filing and for future reference.

Ottumwa, Iowa. A. DOWNING.

Do not open or close a valve until you are sure it is the right valve.

Comments from Readers

Oil Reclaimer on Semi-Diesel

With reference to a contribution in *Power*, Feb. 6, entitled "Using a Lubricating Oil Reclaimer on Semi-Diesel Engines," I wish to say that I believe Colin K. Lee has the right idea.

The lubricating-oil consumption of oil engines is in many instances excessive and often is a considerable percentage of the total operating costs. I would suggest that he use steam in preference to water the next time he has occasion to clean the fifty-gallon fuel-supply tanks. The steam can be passed through the pipe lines, as well, to great advantage. W. E. GREENE.

State College, Pa.

Boiler-Furnace Design

I read with interest the article on "Boiler Furnace Design," by Edwin B. Ricketts, in the April 17 issue. The Utility Companies, however, are not the only ones that are accomplishing results by improved furnace designs.

In the power plant of the Sugarland Industries we installed in 1919 Stirling-type boilers that have a furnace volume of 0.205 to 1.0 of boiler-heating surface, and in 1920 in our sugar refinery we installed some horizontal water-tube boilers which have a furnace volume of 0.28 to 1.0 of heating surface. Since that time all our refinery boilers have been reset with the above ratio of furnace volume to heating surface.

Our fuel is heavy Mexican oil, and at times much of it has been only 12 to 13 deg. Baumé. Our average operative efficiencies of boilers and furnaces range from 76 to 78 per cent.

It is refreshing to know that today many managers are awake to the fact that it is possible to waste many good dollars through inefficient design and operation of their boiler plants.

M. R. WOOD, Consulting Engineer
Sugarland, Tex. The Sugarland Industries.

Removing Scale from Pipes with Muriatic Acid

I read with interest E. L. Gross' discussion in the April 3 issue on the ill effects of removing lime scale from pipes and other apparatus with muriatic acid. From an experience of more than twenty-five years in using undiluted muriatic acid to clean the scale from injector tubes, gas-engine jackets and other apparatus where it was cheaper to use the acid than to tear down the apparatus, I feel that he is unduly apprehensive as to the corrosive effects of this acid. It is only mildly corrosive as to iron and brass, also, the fact that the apparatus limes up is proof that the neutralizing element is present to correct whatever corrosive tendency there is.

In the industry where I am employed, muriatic acid is bought by the carload. Naturally, the engineers use it quite freely for removing the lime from injectors, gas-engine jackets, etc., and it is never diluted, but we had no trouble from corrosion. It is possible that Mr. Gross had sulphuric acid in mind, in which case the effects would be much more serious.

At one time we were doing a lot of pipe work where first-class material was not necessary, and we decided to use some fittings that were badly rusted, so we attempted to remove the rust by suspending them in a tank of sulphuric acid. This would have been successful if we had left them in the acid for a few minutes only, but we forgot to go back to them for a half-hour and by this time they were practically destroyed. So far as iron and steel are concerned, we have had driven-well casings destroyed, also the sulphur in the coal combines with the moisture and attacks our smokestacks as well as the pipe lines in the ground where cinders are in the neighborhood.

Much has been published on the effect that caustic soda or soda ash has on the strength of boiler plates, but we have four 2,000-sq.ft. horizontal return-tubular boilers, 78 in. in diameter, $\frac{11}{16}$-in. shell plates that are nearly 20 years old that have had either soda ash or caustic soda in them practically every day since they were put into operation and so far have not had a dollar's worth of repair work done on them. Furthermore, why is it that some concrete will maintain its strength when soaked in oil, while in other cases it disintegrates under like circumstances and causes considerable trouble? J. O. BENEFIEL.

Anderson, Ind.

The Chief Took the Credit

In reply to the letter in the April 10 issue on "Vibration in Small Direct-Connected Units," I wish to state my experience along this line.

I went firing on a steamboat on Lake Ontario out of Oswego, and among the other equipment the boat had a small vertical engine-driven direct-connected direct-current lighting set. When this was running, we never had to use our fog horn.

One day the chief engineer, who was also the only engineer, started the set up while I was on watch. He said, "I wish I knew what to do to stop that infernal racket and sparking."

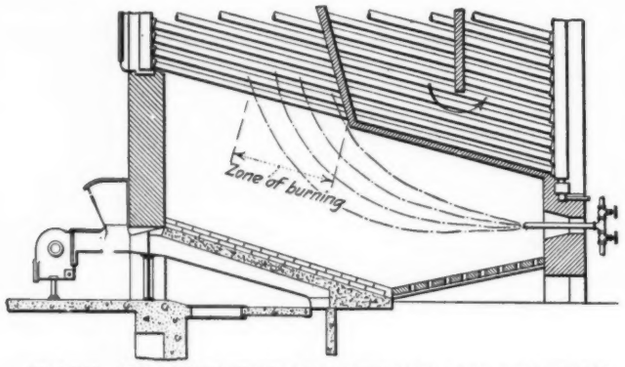
There was considerable sparking, and when the set was shut down in the morning I went at it. I cleaned the brushes and sanded the commutator and then started the unit up. Still the sparking continued. Then I shifted the brush setting till the sparking ceased and the noise stopped at once, and at the same time the voltage went up so high that we had to cut in about one-half the resistance. When the captain and owner came along, the chief said to him, "Well, Cap, I have got her so she doesn't rattle or spark any more."

That chief doesn't know anyting about an electric generator, but he sure knows how to steal credit and apply it to himself. R. G. SUMMERS.

Rochester, N. Y.

What Causes Tubes To Blister When Burning Oil?

Referring to Mr. Hill's letter of March 27, regarding trouble with burning out tubes on an oil-fired boiler, about three years ago I saw a similar instance which was finally cleared up completely. In that case a large station equipped with underfeed stokers and 6,000-sq.ft. water-tube boilers, decided to change to fuel oil on account of the advantageous contract offered, but on



SHOWS ARRANGEMENT OF BAFFLING AND LOCATION OF BURNER

account of the low setting and preferring to keep the stokers in place, rebaffled the boilers similar to the cross-drum type and introduced the oil burners from the rear under the mud drum. The stokers were covered with cinders and two layers of firebrick, and the dumps and ashpits were bricked over. The burners installed were of the steam-atomizing, flat-flame type with checkerwork underneath, three burners per boiler.

On starting up, it was found impossible to develop more than about 150 per cent of capacity without serious danger of blistering tubes, and not more than 10.5 to 11.0 per cent CO_2 could be obtained without smoke. This was a serious matter, as with coal it had been easy to obtain 250 to 300 per cent rating and there was no great excess of boiler capacity available.

The tubes were examined for scale, and while no great amount was found, there were patches from paper thickness up to $\frac{1}{64}$ in., which ordinarily would not be considered at all bad. Metallographic examination of the tubes close to the blisters showed normal metal, and it seemed finally to narrow down to burner arrangement. All sorts of checkerwork was tried, but as soon as an attempt was made to force the boilers the tubes blistered and failed in a zone about three feet wide in front of the vertical baffle. Visual examination of the furnace showed, instead of the transparent, misty flame, practically filling the furnace, which is necessary for the best results, a streaky, almost opaque yellow flame following a sharply defined path from the burner up into the tubes, as shown in the illustration. All the blisters occurred in the zone where this flame impinged on the tubes, and the evidence seemed conclusive that the small quantity of scale present, together with the concentrated heat of the flame, was causing the trouble. After considerable experimenting, we were still unable to overcome the difficulty, so the burners were eventually replaced with the pressure-atomizing type with forced-draft air admission through a conical register surrounding the burner, and the trouble was entirely overcome, as 300 per cent of rating output can easily be obtained and the excess air is reduced to 10 per cent without smoke or unburned gases. Looking into the furnace now, there is no clearly defined flame visible, the whole furnace being filled with a sort of intensely luminous haze.

I would suggest that Mr. Hill adjust his burners to give as short and bushy a flame as possible, also a little experimenting done with the spacing of checkerwork below the burners may prove of value, as the furnace volume shown in his sketch should be ample for any reasonable capacity. The flame should be observed to see whether it concentrates at any one point on the tubes, and the tubes should be kept as clean as possible, for with the intense heats occurring with oil firing, scale that would ordinarily seem unobjectionable may cause serious trouble.

It is essential in boiler firing with oil that combustion be complete before the flame strikes the tubes; otherwise, trouble is sure to occur. I have seen perfectly clean new tubes burned through just above the lower drum on high-capacity tests of torpedo-boat type marine boilers, owing to the intense heat of the flame striking them.

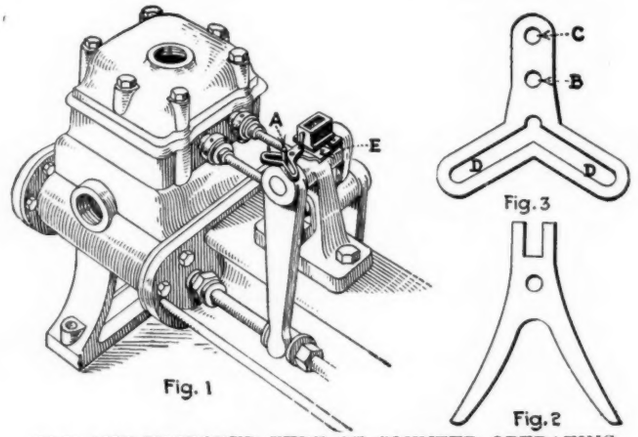
H. D. FISHER.

Colver, Pa.

Improved "Revolution Counter Attachment"

Some time ago there was illustrated and described in *Power*, a revolution counter rig for a pump or other machine, to give an accurate count regardless of a variation in the length of the stroke of the pump.

In this attachment the counter was operated by a forked lever, shown in Fig. 2, which engaged the counter arm at one end and was shoved back and forth by the pump arm. This attachment has one fault. The forked lever can be accidentally knocked entirely out of the



OLD AND IMPROVED TYPE OF COUNTER OPERATING LEVER

path of the pump arm, thereby putting the counter out of service until the lever is pushed back into place. This trouble was overcome by placing a bolt *A* in the top center of the pump arm, and by using a closed forked lever, Fig. 3, made of sheet metal and drilled at *B* for the fulcrum bolt and at *C* for the counter arm. Slots *DD* were cut out, having a width slightly greater than the diameter of the bolt *A*. The counter and lever were mounted on the bracket *E* so that the pin in the pump arm will shove the lever until a predetermined point is reached (a short distance past center) and then follow the slot *D* to the end of the stroke without imparting

any more motion to the lever. If the pump moves past center, as it must to operate, the counter will register the correct number of revolutions, and it is impossible to disengage the lever without dismantling it.

Struthers, Ohio. JOHN V. EMERY.

Making a Right-Angle Turn

The article on "Making a Right-Angle Turn with a Locomotive Crane," by S. C. Page, in the May 1 issue recalls a method that we used a number of years ago in California while erecting refrigerating machinery at the Santa Fe Precooling Plant in San Bernardino.

We had to push heavy carloads of material over a temporary track onto a railroad siding. The temporary track was at right angles to the siding just as in the case cited by Mr. Page.

Instead of jacking up the load, however, our foreman had a derrick located at the junction point. We would wrap chains around the entire car, lift it up an inch or two with the derrick, and then swing the car and its load around 90 deg. The flexibility of the steel cable between the pulley blocks on the derrick permitted us to turn the load easily. The temporary track on top of the siding rails was then removed and the car was lowered onto the siding.

This, in my opinion, is a simpler and better solution than the one offered by Mr. Page, but it is quite possible that in his case there was no derrick large enough to lift the crane and the car, and besides, the right-angle turn was evidently made only once, whereas in our case we have made the turn many times during a day's work. F. M. REILLY.

Newark, N. J.

A Necessary Feature in Adapting Small Turbines to Higher Temperatures

This is the age of mammoth apparatus and of such high steam pressures and total temperatures as to make even our most eminent engineers hesitate in predicting the limiting pressure or total temperature. We all know of 500- and 600-lb. steam pressures and of total temperatures in excess of 750 deg. Just as these increasingly high temperatures have rendered obsolete the main generating unit of yesterday, so has the builder of small turbines been compelled to alter his vision and thought as to the requirements of the small turbine auxiliary for modern power-station work.

Prior to the advent of the superpower-plant steam-operating conditions, which are rapidly being taken up by the small plant as well, the public became familiar with the well-known auxiliary turbine with feet cast integrally with its casing or cylinder. This turbine is connected to the driven member by means of a flexible coupling in which provision has been made to compensate for the expansion, taking place in the turbine casing, between the hot and cold conditions.

Times have changed and so has the more modern small turbine thought, with the engineer, the operator and the manufacturer. Consider for a moment what happens in one of these modern stations of high total temperatures! Take the case of a centrifugal pump or blower. The blower or pump is required to handle water or air at relatively low temperatures, and even at low steam temperatures in the turbine casing the turbine has measurably far greater expansion than the driven member. This unequal expansion has been the chief cause of most of the troubles experienced with the small turbine.

As steam temperatures continued in their upward trend, the matter of permanent alignment became a greater and more difficult problem, until modern power-plant engineers demanded the same attention to the causes of these troubles in the small turbines as had been manifested in the case of the larger units.

Any form of turbine, with feet cast integrally with its casing and tied down to its foundation in such a manner as to expand in an upward direction, will necessarily carry the shaft with it, thus throwing the turbine shaft out of alignment with the driven shaft. This condition causes abnormal strains on the coupling, which in turn cause vibration with its usual effects of bearing and gland troubles, eventually wearing out the turbine and the driven member completely.

This condition called for special thought on the part of the small-turbine designer, and it also resulted in the demand by the superpower-station operators that the small or auxiliary turbine to meet this requirement be, in effect, the equal in design and detail of the main generating unit which it serves.

In this connection there is everything to be said in favor of a casing or cylinder supported at the center, for the reason that this casing can expand in all directions without in any way disturbing the center of shaft alignment with respect to the coupling and driven shaft. The reasons are obvious—smoother operation because of less vibration, hence greater reliability and maintenance; elimination of the troubles that go hand in hand with misalignment, namely, excessive wear on coupling, glands, and bearings; and in addition it relieves the strain imposed on the driven member.

Troy, N. Y. G. W. PENTHENY.

Comments on the Price of Coal

The April 24 issue of *Power* on page 644 carries a paragraph containing a "recent communication" from the United Mine Workers to the Federal Coal Commission, alleging that the operators were charging $4 to $7.50 a ton for West Virginia coal. Also editorial comment, saying that the public, as well as the miners, would like to know the reason why.

The Pittsburgh vein is the best of the four veins of coal in this part of West Virginia and was selling, on the date of publication of the paragraph mentioned, at $2 a ton for run-of-mine, f.o.b. at mines, in lots of one carload up, to anyone who wished to buy—this from a mine capable of loading 40 cars of 60 tons' capacity each working day.

The price for the last four months has ranged from $2 to $3 a ton for run-of-mine, f.o.b. at mine. The writer is in a position to form an unbiased opinion and believes that the mine worker is getting a fine wage for his intermittent, dangerous toil, the operator is getting a fair price for his product, but the middleman gets the most of it—as usual.

The old ship is launched on the sea of prosperity; let's boost her along! A. S. FERRY.

Broomfield, W. Va.

Distribution of operating expenses for a large power house indicates that among these items, fuel amounts to 72 per cent, wages 9 per cent, maintenance of the boiler plant and equipment 6.8 per cent, steam turbines, pumps and auxiliaries 2.5 per cent.

QUESTIONS AND ANSWERS

Conducted by Franklin VanWinkle

Annealing of Boiler Tubes

Do the ends of boiler tubes as received from the manufacturers have to be annealed before they are expanded in water-tube boilers? A. E. D.

Modern standard boiler tubes, furnished by reputable manufacturers, are made of mild steel, properly annealed before leaving the tube mills, ready for ordinary expanding without additional annealing.

Determining Tightness of Vacuum Line or Condenser

What is the best indication of tightness of a vacuum line or of a condenser? W. L. T.

If a vacuum line or a condenser is tight, the vacuum gage will show no appreciable diminution of vacuum for an hour, but when the vacuum drops quickly it is an indication of an air leak. Leaks are readily located by bringing the flame of a lighted match or candle close to all possible places of leakage. The flame will be drawn strongly toward the leaks by the current of air that is drawn into the system.

Soft-Metal Packing Rings

What is a good composition for soft-metal packing rings for piston and valve rods? R. L. B.

Packing rings giving satisfactory results have been made of compositions in various proportions of copper, tin, zinc, antimony and lead. Machined and cut rings made of ordinary babbitt metals have been used with fair success. Good results have been obtained using an alloy consisting of 83⅓ per cent lead, 8⅓ per cent tin and 8⅓ per cent antimony. For use with superheated steam, tin should be omitted on account of its low melting point, and the alloy should consist of 80 per cent lead and 20 per cent antimony. Durability of metallic packings and satisfactory service require the rods to be smooth and true and the packing rings to be machined to sizes that will result in a good fit on the rods when the packing is first used.

Water Trouble with High-Speed Engine

Of late, unless the drips are left slightly open on one of our horizontal high-speed engines, we have trouble from water in the cylinder. This engine is in a cool place, but has only recently given this trouble. The slide-valve setting is unchanged and there is proper piston-travel clearance. What causes the water hammer? G. V. A.

Loading and all other conditions being the same, it is likely that the steam supplied is not as dry as formerly. There should be a separator in the steam line, and if one has been in use, it may not be kept properly drained of water. Or if a separator was not used, there may be more condensation than formerly from greater exposure or poorer condition of the steam-pipe covering. However, in a well-appointed plant the most likely source of the trouble would be poorer quality of steam supplied by the boiler, due to foaming from forcing the fire or use of dirty or greasy feed water.

Percentage Slip of Pump

What is the percentage slip of a double-acting pump having 6-in. diameter water piston, 12-in. stroke and 1½-in. diameter piston rod, making 50 single strokes per minute and discharging 3,970 gal. of water per hour? H. W.

The area of the water piston is $6 \times 6 \times 0.7854 = 28.274$ sq.in., and the piston displacement in the head end of the cylinder would be ½ of $50 \times 28.274 \times 12 = 8{,}482.2$ cu.in. per min. The cross-sectional area of the piston rod is $1\frac{1}{2} \times 1\frac{1}{2} \times 0.7854 = 1.767$ sq.in., hence the net area of the piston on the rod side is $28.274 - 1.767 = 26.507$ sq.in., and the piston displacement in the rod end of the cylinder would be ½ of $50 \times 26.507 \times 12 = 7{,}952.1$ cu.in. per min., and the total piston displacement would be $8{,}482.2 + 7{,}952.1 = 16{,}434.3$ cu.in. per min., or $16{,}434.3 \times 60 = 986{,}058$ cu.in. per hour. An actual discharge of 3,970 gal. per hour would be equal to $3{,}970 \times 231 = 917{,}070$ cu.in. per min. Therefore the slippage would be $986{,}058 - 917{,}070 = 68{,}988$ cu.in., which is $68{,}988 \div 986{,}058 = 0.069$, or practically 7 per cent.

Equalizing Temperature in Hot-Water Tank

We have a closed hot-water tank that is fitted with a steam coil and used for supplying hot water to a large apartment house. The water becomes too warm at times when there is a light draft of hot water and too cold when the largest drafts take place. How can the temperature of the water be held more nearly uniform? J. F. C.

The cold-water supply should be heated on its way to the tank, and the steam supply to the tank coil should be regulated by a thermostat or otherwise for simply holding the tank water to the desired temperature.

The initial heating of the water before admission to the main tank should be performed in a heater having small water capacity with the heating capacity cut down to meet the maximum demand at the desired maximum temperature. Then when the main supply tank water and heater water have been standing for a long time only the first draft of tank water to the extent of the small water capacity of the heater will be replenished by water of higher temperature than the desired tank temperature.

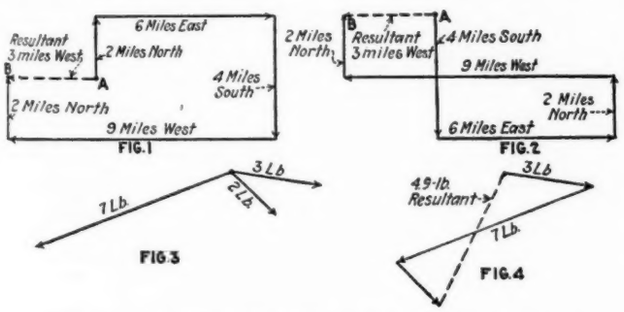
Easy Lessons in Engineering

Solving Problems with Vectors

So many engineering problems are readily solved with the aid of "vectors" that some knowledge of the subject should be of value to any engineer. The fundamental idea is extremely simple. A "vector quantity" is one that has both amount and direction. For example, "five miles north" is a vector quantity, as is also a "velocity of 8 ft. per second southeast" or a "force of 5 lb. acting vertically downward."

Any vector quantity can be represented by an arrow whose direction is the direction of the motion, velocity, force, etc., and whose length represents the quantity to some predetermined scale. This arrow is the vector. For example, the vector quantity "five miles north" could be represented by an arrow or "vector" pointing north and 5 in. long.

Vectors can be added and subtracted. The sum of several vectors is merely the final net result of all of them as represented by another vector, called the "resultant." To get the idea, consider the simple case of a man starting from a certain point *A* and walking 2 miles north, 6 east, 4 south, 9 west and 2 north. Fig. 1 shows the actual path he travels. The final result is that he lands at *B*, 3 miles due west of his starting point. He could have accomplished the same result by a single movement of 3 miles due west, as indicated by the dotted arrow. This is called the resultant or the sum of five vectors. Note that *in getting the sum the vectors are placed end on end with the arrows all*



FIGS. 1 TO 4—VECTORS ADDED BY PLACING THEM END ON END

running around the same way. Then a single line drawn from the beginning of the first arrow to the end of the last arrow is the resultant and represents the net effect or sum of all the separate vectors. This can be taken as a rule for adding vectors of any sort. In addition it may be stated that the order in which the vectors are added makes no difference. For example, the same movements have been added up in a different order in Fig. 2, the sequence being 4 miles south, 6 miles east, 2 miles north, 9 miles west and 2 miles north. Here the resultant is exactly the same as before.

Perhaps the most frequent application of vectors is in problems involving forces. Suppose three forces are acting at one point, as indicated by the three vectors shown in Fig. 3. The net effect is the sum of these three vectors obtained by placing them end on end in any order (keeping the arrows running around in the same sense) and drawing a vector from the beginning of the first to the end of the last. This is done in

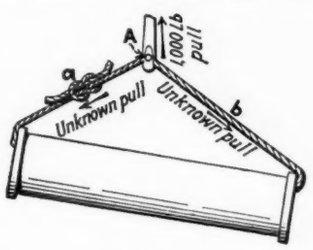


FIG. 5

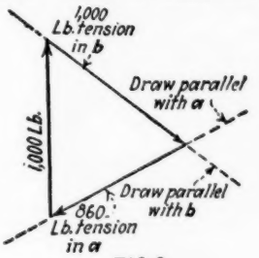


FIG. 6

FIGS. 5 AND 6—CONSTRUCTION FOR FINDING TENSIONS IN ROPE

Fig. 4, the vectors being drawn parallel to their original directions with the aid of a straight-edge and triangle. The resultant shows the direction and amount (to the same scale) of the single force equivalent to the three.

Many problems in forces involve what is known as equilibrium. If no force is acting on a body, it does not change the direction or speed of its motion, and if it is standing still it remains at rest. Conversely, if any body is at rest or moving at constant speed in a straight line, the net effect, or resultant of all the forces acting upon it, must be zero.

This means that in such a case the sum of the vectors must be zero, so that when the vectors are placed end on end in any order, the point of the last arrow must fall on the beginning of the first. This principle is very useful in solving problems.

For example, a casting weighing 1,000 lb. is hung from a crane hook by a rope sling, as shown in Fig. 5, and it is desired to find the tension in each branch of the rope. Consider the point *A* where the rope crosses the hook. The hook is evidently pulling straight up with a force of 1,000 lb. as shown. The two branches of the rope are pulling on the same point in the *directions* shown, but the corresponding vectors cannot be drawn because the *amounts* of these pulls are unknown.

Now if we can draw a figure with the 1,000-lb. vector placed end on end with two others, so that the end of the last one falls on the beginning of the 1,000-lb. vector, we shall have solved the problem. Lay out the 1,000-lb. vector as shown in Fig. 6. Through one end draw a line parallel to *a*, and through the other draw a line parallel to *b*. Then put in the arrowheads as shown (all running around in the same sense) and measure off the forces to the same scale as used in plotting the 1,000 lb.

SUMMARY OF SERVICE DISTURBANCES COMPARED FOR 5-YEAR PERIODS — 1911 to 1917 and 1918 to 1922

CAUSE	TOTAL INTERRUPTIONS										PARTIAL INTERRUPTIONS										VOLTAGE DISTURBANCES									
	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	5 Yr. Total	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	5 Yr. Total
1 Ice		1					0						0								1					0		1			2
2 Breakdown of Power House Equipment	2	1			1		1						0	2	3	2		1			1					0	2	17	5	1	25		1			1	6	7
3 Excitation System, Regulator, etc.			1				1						0			1					0					0	10	5		1							1
4 Gates & Governor System							0						0								7					0	12	5		1							1
5 Holtwood Bldgs.	1	1	1	1	1	2	5	0	1	0	0	0	1	4	5	1					7	0	0	2	0	2	17	23	49	10	8	8	8	83	5	5	5	3	30
1 to 5 Totals	3	3	2	1	1	2	7	0	2	0	0	0	2	7	8	2	0	1	0	0	11	0	0	2	0	2	34	10	4	13	11	20	6	14	6	14	6	10	5	7	48
6 Lightning on Transmission Line	23	3	3	1	3		7	2	2				4			19		19	6	15	2	7	47	15	3	3	6	6	33	10	4	11	7	8	5	7	38	20	6	10	5	7	48
7 Birds on Transmission Line	1			1		2	5						0					3	2	2			9				0				2	8			12	3				5
8 Mechanical Trouble on Line (Sleet)					1		2						0					3	2	2			9				0				2	4	1	7	14	3	2	1	1	7
9 Transmission Line Miscellaneous	24	3	4	4	4	0	2	14	2	2	0	0	4	0	19	19	12	16	4	9	60	15	5	4	6	6	34	10	4	13	11	20	6	14	64	25	11	11	5	10	60
6 to 9 Totals	24	3	4	4	4	0	2	14	2	2	0	0	4	0	19	19	12	16	4	9	60	15	5	4	6	6	34	10	4	13	11	20	6	14	64	25	11	11	5	10	60
10 Hillandtown Equipment									1	1			2					1	0	0	2	0	1	1	1	1	5	0	0	0	0	1	0	1	0	1	1	1	1	5
11 Hillandtown Wirebase	0	0	0	0	0	1	1	1	1	1	1	0	5	0	0	0	0	1	0	2	3	2	0	1	1	1	6	0	0	0	0	1	0	1	1	6	14	5	2	8	31
10 and 11 Totals	0	0	0	0	0	1	1	2	2	2	1	0	5	0	0	0	0	1	0	2	5	2	0	2	1	2	11	0	0	0	0	2	0	2	2	12	15	6	4	15	52
12 Distrib. System & Customers' Equip.	3	3	2	1		1	4	1					1	2	19	11	27	18	31	47	134	38	39	33	51	67	238	1		4	14	11	24	21	74	64	68	62	47	32	273
13 Overload							0						0								0						0	1	5	4	8	3	1	2	18	34	15	12	2	65
14 Lancaster System							0						0								1						0				24	5	2	5	36	1	4	17	5	5	9
15 Miscellaneous	2						0						0					1			5				7	4	11					1	2	1	2	26				40	70	4	114
16 Tests	1	2	1				3						0								2						0					3	9	2	12	26	1					1
17 Men in Contact with Live Conductor	2		1				3						0								1						0								1						1
12 to 17 totals	8	5	4	1	0	0	3	1	0	0	0	0	1	2	23	18	27	19	31	47	142	38	39	33	51	67	238	1	5	9	18	46	32	29	30	157	105	86	131	141	59	525
TOTALS	35	11	10	6	5	1	8	30	5	5	0	1	11	4	49	45	42	35	35	58	216	55	42	38	47	110*	292*	32	36	80	69	80	43	53	305	141	119	138	133	75	646
LOCATION OF TROUBLE																																									
1 Holtwood Power House	2	4	3	1	1	1	4	10		1			1		4	4	3		1		8					2	0	16	29	18	19	23	9	10	107	6	6	15	10	3	39
2 Safe. H.T. Transmission Line	24	3	5	4	4		2	15	2	2			4		10	17	11	17	4	9	68	15	3	4	6	6	34	10	4	13	11	21	6	14	65	23	11	12	5	10	61
3 Hillandtown Substation	4	1	2	1			2	2	2	2	1		5		1	2	1	2	1	5	6	2	1	2	1	2	6	4	1						7	16	6	2	6	37
4 Balto. Distrib. System Incl. Cust. Equip.	5	3	2	1			3	1					1		4	23	19	27	18	51	46	141	38	39	35	58	102	250	2	2	1	20	14	11	26	23	94	97	85	108	119	39	446
5 Lancaster System							0						0								0						0			1	24	5	2	5	37	7	4	17	17	20	65
6 Unknown							0						0								0						0								1						1
TOTALS	35	11	10	6	5	1	8	30	5	5	0	1	11	4	49	45	42	35	35	58	216	55	42	38	47	110*	292*	32	36	80	69	80	43	53	305	141	119	138	133	75	646
SYSTEM OF ORIGINAL TROUBLE																																									
1 Pennsylvania Water & Power Co.	31	8	8	5	5	1	8	27	4	5		1	10	* 1	28	27	24	18	8	18	95	22	9	5	14	9	59	30	35	57	31	45	24	25	182	41	32	34	23	25	155
2 United Railways Company's System	2	1	2	1				3	1				1		5	2	6	5	6	9	28	6	4	9	7	11	37	1		3	5	3	4	4	17	6	8	9	5	4	32
3 Consol. Gas, E.L. & P. Co.'s System	2	2						0					0		3	16	13	12	12	22	78	27	29	24	26	24	130	1	1	19	11	7	13	19	69	86	75	98	109	29	396
4 Lancaster Edison Co.'s System								0					0			3					3						0			1	24	5	2	5	37	7	4	17	17	20	65
5 Unknown								0					0								0						0								1						1
TOTALS	35	11	10	6	5	1	8	30	5	5	0	1	11	4	49	45	42	35	36	58	216	55	42	38	47	114*	306*	32	36	80	69	80	45	53	305	141	119	138	133	75	646

* Figures do not check on account of some being classified in two places.

Reducing Power Interruptions*

By F. A. Allner†

The classification of disturbances given in the table are those developed during the last ten years of combined hydro-steam operation in the Baltimore-Lancaster load centers where the Pennsylvania Water & Power Co. furnishes the hydro power from a run-of-river development on the Susquehanna River in Holtwood, Pa. As to the service standard of the Holtwood-Baltimore-Lancaster system, specific results grouped progressively for the individual years and for five-year periods are presented. These records refer only to the few minutes and seconds and fractions thereof when service was not 100 per cent perfect, regardless of whether trouble originated on the hydro system proper or at the steam plants operated in parallel or on the general distribution system.

Under the standard adopted for the Holtwood-Baltimore-Lancaster system a total loss of load, be it for only a second, is classified as a total interruption; a partial loss of load, provided same can be traced on the main station instruments, is classified as a partial interruption; irregularities in voltage or frequency, exceeding 4 per cent in voltage and 2 per cent in frequency, are classified as disturbances, although no visible loss of load can be traced on the graphic wattmeters.

The statistics illustrate more convincingly than can be done by general statements that hydro-plant troubles as such—that is, those numbered 1 to 5 on the tabulation—ceased to be the cause of interruption after a few years, although they were responsible for a few serious disturbances during the initial period of operation at Holtwood. For example, ice caused one complete shutdown on Jan. 5, 1912, about one year after beginning operation. Up to that time the general impression was that a plant located almost at the Mason-Dixon line with a storage lake nine miles long would be immune against frazil ice. The tabulation shows only one more trouble, Feb. 14, 1914, from this cause and then it was frazil and anchor ice combined and only a partial service reduction. No more trouble occurred from this source after 1914. All the other causes of trouble at the hydraulic plant, causes 2 to 5, show a similar trend.

The interesting experience in regard to transmission line and distribution trouble will be referred to briefly. Lightning in the first year of operation, 1911, caused 23 total interruptions of a few seconds or a minute each, none of them causing any permanent disabling of line. Chiefly due to the use of the Nicholson arc extinguisher, this number was reduced in the following year, 1912, to three; in the next five-year period to an average of 1.4 and in the last five years to an average of 0.8 per year. There have been no total interruptions from lightning at all during the last three years.

Distribution troubles, chiefly those originating on the city distribution system and at the interconnected steam plants, show a trend in the opposite direction, at least for partial interruptions. The number of partial interruptions from this cause rose to 238 in the last five years, from 134 during the preceding five-year period; minor disturbances to voltage and frequency to 273 from 74. This condition has caused the operating engineers to concentrate their studies in more recent years on the distribution problem as the principal field for possible electric-power service improvements.

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*Abstract from a paper, "Quality of Hydro-Electric Service," presented before a joint meeting of the A. I. E. E., A. S. M. E., A.S. C. E. and A. I. M. E., New York, 1923.

†General Superintendent, Pennsylvania Water and Power Co.

Superpower Survey of the Pacific Northwest*

In 1921 a Superpower Survey Committee was created through various engineering organizations acting in conjunction with Chambers of Commerce in the Pacific Northwest. Its personnel includes representative engineers in educational institutions, in private practice, and in municipal and corporation utilities. The object of the survey was "to obtain an authoritative and reliable compilation of data to be made available to the public, to capital, to existing and future operating companies, to industries in general and to commercial and legislative bodies; and to further industrial development by an attempt to forecast and indicate such methods of power expansion, development, and interconnection as may ultimately prove sound." The committee members have served without compensation, and have defrayed all expenses connected with the work except for drafting and printing, which was paid by the Portland Chamber of Commerce. This committee has recently presented its report.

Data on which this report is based were secured through questionnaires sent to each municipal and public utility. The field comprised in the study covers the States of Washington, Idaho and Oregon. Power developments in these states naturally divide themselves into five groups, within each of which power plants are interconnected or can be connected at slight expense. Data have been secured from utilities producing over 90 per cent of the total power generated. Utilities which have sent in complete reports are listed in five major groups as follows:

1. Puget Sound Group: City of Seattle, City of Tacoma, Puget Sound Power & Light Co., and Olympia Light & Power Co.

2. Upper Columbia Group: Washington Water Power Co. and Pacific Power & Light Co. (Yakima-Walla Walla Division).

3. Lower Columbia Group: Portland Railway, Light & Power Co., Northwestern Electric Co., Pacific Power & Light Co. (the Dalles-Hood River and Astoria Divisions), and North Coast Power Co.

4. Snake River Group: Idaho Power Co., Eastern Oregon Light & Power Co., and Cornucopia Mines Co.

5. Southern Oregon Group: The California Oregon Power Co. and Mountain States Power Co.

Table I shows the average load conditions by groups for the year 1921:

TABLE I—AVERAGE LOAD CONDITIONS BY GROUPS, 1921

Group	Average Load	Peak Load	Annual Load Factor Per Cent
Puget Sound	68,000 kw.	156,000 kw.	44
Lower Columbia	50,000	92,000	54
Southern Oregon	17,000	25,000	68
Upper Columbia	51,000	82,000	62
Snake River	24,000	37,000	65
All groups	210,000 kw.	392,000 kw.	54

Table II gives the total power in kilowatt-hours generated in each group during 1921, both by steam and hydro-plants:

TABLE II—TOTAL POWER GENERATED, 1921

Group	Power Generated—Kilowatt Hours Steam	Hydro	Total	Steam Per Cent of Total
Puget Sound	30,493,000	561,534,000	592,027,000	5.2
Lower Columbia	73,410,000	360,416,000	433,826,000	16.80
Southern Oregon	11,350,000	152,020,000	163,370,000	6.9
Upper Columbia	61,000	443,838,000	443,899,000	.015
Snake River	1,260,000	202,018,000	203,278,000	1.6
All groups	116,574,000	1,719,826,000	1,836,400,000	6.3

The total energy generated in 1921 in all groups, as reported, was nearly two billion kilowatt-hours. To produce the amount of energy by coal which is now produced by hydraulic power would require the consumption of about two million tons annually.

The average load for the Northwest has nearly doubled in the last five years. The increase during the last seven years was 122 per cent.

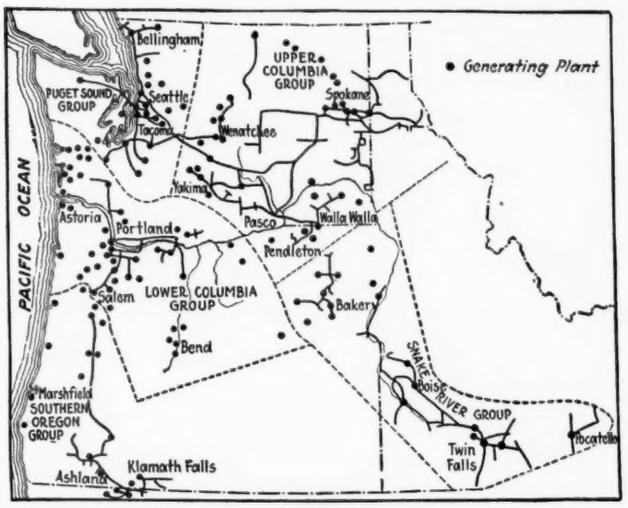
*Abstract from Report of Superpower Survey Committee of Pacific Northwest.

The probable effective station capacity on basis of present development plans is shown in Table III:

TABLE III—PROBABLE EFFECTIVE STATION CAPACITY

Group	Peak Load	Probable Future Effective Station Hydro and Steam Capacities in Thousands of Kilowatts at end of Year				
	1921	1923	1924	1925	1926	1927
Puget Sound	156	192	248	248	332	332
Lower Columbia	92	115	154	154	179	204
Southern Oregon	25	33	33	43	45	45
Upper Columbia	82	135	143	143	156	156
Snake River	37	54	54	63	63	74
All groups	392	529	632	651	775	811

Accompanying this report is a map, shown herewith, of the Pacific Northwest showing the location of the more important commercial power plants and the general system of connecting transmission lines as they existed on May 1, 1923.



MAP OF THE PACIFIC NORTHWEST, SHOWING THE LOCATION OF THE MORE IMPORTANT COMMERCIAL POWER PLANTS AND THE GENERAL SYSTEM OF CONNECTING TRANSMISSION LINES AS THEY EXISTED ON MAY 1, 1923

Conclusions

The committee, after a careful study of the data secured, has classified the power systems of the Pacific Northwest into five major groups and has reached the following general conclusions:

1. There is a healthy increase of power demand in all groups.

2. Adequate provisions are under way in all groups to keep ahead of the estimated growing demand by the construction of hydro-plants and water storage. In the groups where steam power production is now an important element, plans provide for reduction of the proportionate amount of power supplied by steam.

3. The characteristics of the power load of each group are much the same, the maximum load occurring in the fall and winter, except in the Snake River group, where irrigation pumping produces a summer peak.

4. The need of group connection by superpower lines is at present not sufficiently great to justify the expense even in the case of a line between the Snake River and Upper Columbia groups where the advantage would be greatest.

5. The power which can be economically exchanged between the several groups can be carried over ordinary transmission lines already built or likely to be built in the future.

6. Existing networks of power systems will, through natural expansion, become more closely interconnected, but superpower lines are not likely to be needed unless economical development in one group reaches its limit while great excess of power exists in other groups. Such a condition is not likely to obtain for many years.

7. Future large hydro-power development, in addition to

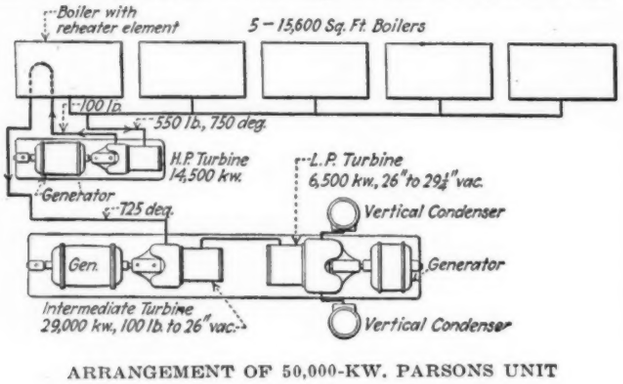
that provided by existing systems normally expanding, is dependent upon the introduction of commercially feasible agricultural or industrial enterprises requiring large amounts of power.

8. Such power development is of the highest importance to the Northwest. If wisely undertaken, it will come as a result of newly created markets, will tend to benefit other public utilities and stabilize rates, but will not in itself require superpower connection.

9. Thirty-eight per cent of the water-power possibilities in the United States are located in the area under discussion. The development work up to the present time has in the main been consistently carried along without unnecessary duplication. The expense of superpower construction, which must be incurred in other regions to save fuel or to equalize unbalanced power conditions, can be avoided for a long time in the Pacific Northwest. Superpower lines may, however, become of importance at an early date to carry power from our abundance to less favored regions to the south and east.

Compound Turbines and Reheating for Crawford Avenue Plant

The Commonwealth Edison Co., of Chicago, broke ground early in March for its new Crawford Avenue Station, which will be located on the Drainage Canal about eight miles from the center of the city. The plant is laid out for an ultimate capacity of 500,000 kw. A steam pressure of 550 lb. and temperature of 750 deg. F. will be carried at the



ARRANGEMENT OF 50,000-KW. PARSONS UNIT

turbines. Provision will be made for reheating the steam at about 100 lb. pressure to a temperature of 725 deg. F.

As previously announced in *Power*, three turbines have been ordered for the first installation. Unit No. 1 will be built by C. A. Parsons & Co., Ltd., of Newcastle-upon-Tyne, England. This unit is of 50,000-kw. capacity and has an unusual arrangement, consisting of three turbines, a 14,500-kw. high-pressure element running at 1,800 r.p.m., a 29,000-kw. intermediate turbine running at 1,800 r.p.m. and a 6,500-kw. low-pressure turbine running at 720 r.p.m. Each has its separate generator, but the intermediate and low-pressure turbines are arranged in tandem on the same bedplate with the generators at either end as indicated in the diagram herewith. Unit No. 2 has been ordered from the General Electric Co. and is of 60,000-kw. capacity. It will be a cross-compound machine consisting of a high-pressure turbine running at 1,800 r.p.m. and a low-pressure turbine running at 1,200 r.p.m., each with its separate generator. Unit No. 3 will be a Westinghouse cross-compound unit of 50,000-kw. capacity, consisting of a high-pressure turbine running at 1,800 r.p.m. and a low-pressure turbine at 1,200 r.p.m., each element, as before, having its own generator.

Instead of the usual arrangement all the turbines will be supplied with vertical condensers, two for each unit, these condensers standing alongside of the low-pressure cylinders.

The boilers for the Crawford Avenue plant will be of the Babcock & Wilcox high-pressure design similar to those for the Waukegan Station, a description of which appeared in the Sept. 12, 1922, issue of *Power*, but will be built for a maximum working pressure of 650 lb. per sq.in. For each unit there will be five boilers, each with about 15,600 sq.ft. of steam-making surface except that one boiler on each unit will be of special design and equipped with the "reheater" or interstage superheater.

Informal Conference on Standardizing Pipe Joints at Higher Pressures and Temperatures

Representatives of manufacturers, users, consulting engineers and others interested in pipe flanges for higher steam pressures and temperatures held an informal conference May 23, 1923, at New York City. This was under the auspices of the Sectional Committee on Standardization of Pipe Flanges and Fittings, for which the three following organizations are sponsors: Committee of Manufacturers on Standardization of Fittings and Valves, Heating and Piping Contractors National Association, and the American Society of Mechanical Engineers.

A letter by C. H. Hirsfield, of the Detroit Edison Co., asked, on behalf of the Prime Movers' Committee of the N. E. L. A., that an agreement among the various committees be reached for various pressures and temperatures covering allowable working stresses of different materials; gasket pressure; specification for material and methods of testing; and rational pressure for which standards should be specified.

It was brought out that a small bolt circle for pipe flanges with many small-diameter bolts represents the most desirable flange-holding arrangement. Experiences at high temperatures indicated that heat-treated material and in some instances alloy steel for bolts did not give as good service as machine steel.

Fittings generally exposed to high pressures and temperatures appeared to give better satisfaction when designed for some flexibility rather than excessive strength and rigidity. O. F. Junggren, of the General Electric Co., described some investigation of bolted flanges, as encountered in steam-turbine manufacture. Stresses set up by temperature appeared several times as large as the requirements of mechanical strength. On heating up bolted joints, the flanges absorb heat much more quickly than the bolts. The bolts therefore tend to become stretched by the flange expansion. Some flexibility in a pipe flange is desirable as a means of relieving excessive bolt strain.

Users of pipe fittings as well as manufacturers recommended that in standardizing fittings, as few sizes be used as practicable. This means fewer patterns for the maker and less spare parts for the power plants. New standards appeared desirable. A method of reducing the number of standard fittings, strongly advocated, was to standardize the outside diameter of pipe for a given size and vary the internal diameter to suit pressure conditions. This would make one, or possibly two standard flange diameters possible, from 250 to 1,200 lb. By using the same-sized bolt circle, the bolts themselves could be modified to suit steam pressures. Bolts and flanges may be designed with equal unit stress in both members. Excessive bolt strain is liable to occur in greater degree in the bolts when abnormal conditions arise, thus protecting the flanges. Flange thickness could be varied as desired at the various pressure standards. This principle of standardizing outside diameters appeared equally suitable to valve construction.

G. E. Fox, of the Standard Oil Co., described a distillation process operating at 390 lb. and 800 to 900 deg. F. Joints of 4-in. pipe require dismantling for cleaning at four-day intervals, and explosive gas made absolute tightness a necessity. He advised that best results were obtained with a rough-turned pipe flange, with a surface similar to that of a phonograph disk, using a monel-covered asbestos gasket. Machine-steel bolts gave better satisfaction than alloy steel.

A motion was passed that pressure standards of 250, 400, 600, 800 and 1,200 lb. be recommended. The need of haste was emphasized, as in some cases fittings for 600 lb. and higher were being made with no official standards to follow.

News in the Field of Power

Cheat River Development To Counteract Flood Menace

To the West Virginia Power & Transmission Co. there has been given a preliminary permit for an extensive project on the Cheat River, in West Virginia and Pennsylvania by the Federal Power Commission.

This project includes eleven separate units with a total ultimate installation of 600,00 hp. It will completely develop the power possibilities of Cheat River and will be of great benefit to navigation on the Monongahela River.

Only the lower two or three miles of the Cheat River are navigable, but the river flows into the Monongahela, a stream that has been canalized by a series of locks and dams. During unusually dry seasons there is not sufficient water in the Monongahela to provide for lockages for navigation, and as the Cheat River is an important watershed contributing to the flow of the Monongahela and Ohio Rivers, Congress has appropriated funds at various times to investigate storage possibilities on Cheat River with a view to increasing the low-water flow for navigation in the Monongahela and diminishing flood heights at Pittsburgh, these considerations very materially affecting navigation interests in this important region. The benefits to be derived, however, did not appear to be sufficient to justify the cost and the work has never been undertaken.

The West Virginia Power & Transmission Co.'s project, when completed, will permit an increase in the low-water flow sufficient to meet all the needs of navigation and will aid materially in counteracting the flood menace at Pittsburgh by entirely preventing ordinary floods from the Cheat and diminishing the effect of abnormal floods.

The storage capacity of the proposed reservoirs will probably total a million acre-feet. This abundant storage will permit the development of base power, thus enabling the hydro-electric plants to operate on practically continuous load.

The preliminary permit will contain provisions protecting fully the interests of navigation on the Cheat and Monongahela Rivers.

The American Engineering Standards Committee reports 200 opportunities to simplify power appliances, such as boilers, valves, pumps, pipe supplies and kindred products. This is the preliminary analysis of a survey recently carried on by the committee at the request of Secretary Hoover of the Department of Commerce.

N.E.L.A. Convention To Be Held June 4-8

Partial Program Including Those Papers and Reports Which Are of Particular Interest to "Power" Readers

General and Executive Sessions

TUESDAY, JUNE 5, 9:30 A.M.

Address, Hon. John F. Hylan, Mayor, "Welcome to New York."

Address, Thomas Alva Edison, "Greetings to the Industry."

Committee Reports.

WEDNESDAY, JUNE 6, 9:30 A.M.

Report, Franklin T. Griffith, Water Power Development Committee.

Address, Gen. Guy E. Tripp.

THURSDAY, JUNE 7, 9:30 A.M.

Report, Charles B. Scott, Accident Prevention Committee.

Report, Charles B. Scott, Insurance Committee.

Report, M. S. Sloan, Electrical Resources of the Nation Committee.

FRIDAY, JUNE 8, 9:30 A.M.

Address, O. C. Merrill, Executive Secretary, Federal Water Power Commission.

Report, John W. Lieb, Joint Fuel Committee.

Technical Sessions

MONDAY, JUNE 4, 2:00 P.M.

Report, C. F. Hirshfeld, Prime Movers Committee.

Report, O. G. Thurlow, Hydraulic Power Committee.

Report, R. H. Tapscott, Electrical Apparatus Committee (Generating Stations.)

Symposium Covering, High Steam Pressures, Reheating of Steam, Pulverized Fuel, Useful Life of Turbines, Internal-Combustion Engines, Water-Power Development.

Address, Charles H. Merz, Consulting Engineer, London, Eng.

Address, Fred N. Bushnell, mgr. Construction and Engineering, Stone & Webster, Boston.

Address, A. G. Christie, "Pulverized Fuel for Central Stations."

Address, Peter Junkersfeld, "Useful Life of Turbines."

Address, H. Birchard Taylor, "Comparison of American and European Practices of Waterwheel Construction and Water-Power Development."

TUESDAY, JUNE 5, 2:15 P.M.

Report, Thomas Sproule, "The Status of the Safety Code."

Report, R. H. Tapscott, Electrical Apparatus Committee (Substations and Oil Circuit Breakers.)

WEDNESDAY, JUNE 6, 2:15 P.M.

Report, R. H. Tapscott, Electrical Apparatus Committee. (Motors, Transformers, Radio and Service Voltage.)

Symposium on Transmissions of the Future.

Address, Frank G. Baum, consulting engineer, San Francisco.

Address, William S. Murray, consulting engineer, New York City.

Public Relations

WEDNESDAY, JUNE 6, 2:15 P.M.

Ten Minute talks by M. H. Aylesworth, Hon. W. D. B. Ainey, Commissioner Public Service Commission, Pennsylvania; Hon. Alexander Forward, Commissioner, Virginia State Corporation Commission; Hon. E. V. Kuykendall, Commissioner, Washington Department of Public Works; Hon. James A. Perry, Commissioner, Georgia Public Service Commission; Hon. Clyde M. Reed, Commissioner, Kansas Public Utilities Commission; Hon. William A. Prendergast, Commissioner, Public Service Commission, New York City; Hon. Henry G. Wells, Commissioner, Massachusetts Department of Public Utilities; Martin J. Insull, Vice-President, Middle West Utilities Co.; John B. Miller, President, Southern California Edison Co.; P. S. Arkwright, President, Georgia Railway and Power Co.; W. W. Freeman, President, Union Gas and Electric Co.; J. F. Owens, Vice-President, Oklahoma Gas and Electric Co.; Arthur Williams, General Commercial Manager, New York Edison Co.

Customer Ownership

THURSDAY, JUNE 7, 2:30 P.M.

Address, B. C. Forbes, Editor, Forbes Magazine, New York City.

Address, Samuel Insull, President, Commonwealth Edison Co., Chicago, Ill.

Address, Louis H. Egan, President, Union Electric Light and Power Co., St., Louis, Mo.

Address, E. K. Hall, Vice-President, American Telephone and Telegraph Co., New York City.

Address, John A. Britton, Vice President, Pacific Gas and Electric Co., San Francisco.

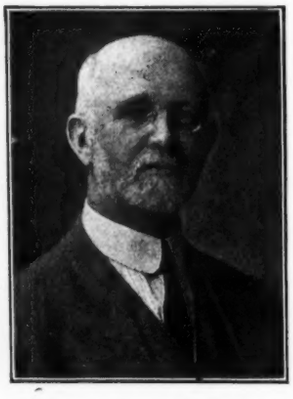
Public Policy

THURSDAY, JUNE 7, 9:00 P.M.

Address Julius H. Barnes, President, Chamber of Commerce of the United States of America.

Prof. Breckenridge Receives Farewell Testimonials

As an outstanding figure in the broad field of mechanical engineering, Lester P. Breckenridge, Professor of Mechanical Engineering in Yale University, was signally honored at the May 21 meeting of the New Haven (Conn.) branch of the A.S.M.E. Business was laid aside, the meeting taking the form of a magnificent farewell to Professor Breckenridge, who, at the age of 65, is retiring from teaching and active engineering work. Speeches were made by Calvin W. Rice, secretary of the A.S.M.E., Fred J. Miller, past president of the A.S.M.E.; George A. Orrok, consulting engineer, and Henry Kreisinger, United States Bureau of Mines. Among those sending letters and telegrams of esteem were: James Hartness, Governor of Vermont; Ambrose Swasey, past president of the A.S.M.E.; the



LESTER P. BRECKENRIDGE

faculty of the University of Illinois; Dean M. E. Cooley, University of Michigan; and Fred. R. Low, editor of *Power*. These speeches and messages were a powerful demonstration of the respect and affection which thousands of engineers hold for Professor Breckenridge as a pioneer in many branches of engineering, as a teacher, and—above all—as a man.

Professor Breckenridge gave some interesting reminiscences of his forty years of engineering work while teaching at Lehigh, Michigan Agricultural College, Illinois and Yale. He told of experiences in many fields—pioneer turbine tests in the first flume at Holyoke in 1881; development work with centrifugal pumps; extensive researches on the burning of fuels; tests of locomotives, the first Porter-Allen engine and the first big steam turbine; special work in heating and ventilation.

A beautifully engrossed expression of its esteem was presented by the New Haven Branch. At the close of the college year Professor Breckenridge, who is still in full physical and mental vigor, will move to his farm in Vermont and devote himself to his hobbies, which are nature study and travel.

Luncheon Given in Honor of Dr. De Margerie

A luncheon to mark the appreciation of the members of the engineering profession in the United States of the significance of the interchange of leaders in scientific and engineering education was given at the Harvard Club, New York, on Friday, May 18, in honor of Dr. Emmanuel de Margerie, on the completion of his term as visiting professor to a group of American Universities, in an exchange of professors with the Ministry of Education of the French Republic.

Members of the boards of directors of the four professional engineering societies and representatives of the government of France were present to the number of sixty-odd. Dr. Albert R. Ledoux acted as toastmaster and introduced Dr. A. E. Kennelly, last year exchange professor from the United States to France, to whose appreciation of his services and of the relations existing between the engineers and scientists of the two countries Dr. de Margerie responded in fitting terms. In the enforced absence of Ambassador Jules Jusserand, Charles Baret, the recently appointed Consul General at New York, and M. Gaston Liebert, who has just vacated the post of Consul General, to become director of the French Bureau of Information spoke.

A. S. H. & V. E. Meet in Chicago

From May 21 to 23 the American Society of Heating and Ventilating Engineers held the semi-annual meeting at the Drake Hotel, Chicago. The attendance was close to 600.

At the business session Monday morning a gratifying increase in membership was reported, the roster showing a total of 1,684. In addition 118 new members had been passed upon and applications are in for 130 more.

Out of 144 letter ballots on the new constitution and by-laws, approved with certain corrections and additions at the Washington meeting, only two negative votes were reported. Mention was made of the code on steel-plate and cast-iron heating boilers soon to be published by the A.S.M.E., and of the new code of the Department of Commerce on small building construction containing sections on chimneys and heating appliances. An important action at this session was the adoption of a standard code for testing fans.

Afternoon and evening sessions were given over to discussion of the new code of minimum requirements for the heating and ventilation of buildings. It is hoped that the code in tentative form may be ready for the annual meeting. It will eliminate rule-of-thumb methods by standardizing fundamental formulas and methods to be employed in the design of heating and ventilating installations as a whole and the application of various equipment. It is to be written so that it may be incorporated as a part of municipal building codes.

Tuesday was research day. With an assured income of $24,000 for the year, E. E. McNair stated that work had been laid out for a budget of $31,000. The balance was in sight and if an additional $10,000 could be secured, more work of urgent character could be undertaken. F. Paul Anderson, director of the Research Laboratory, spoke briefly of the activities of the Laboratory, while various members of his staff presented research reports. Of work to be conducted within the next six months, Professor Anderson mentioned an investigation to determine the size of dry and wet returns. A heat meter that would actually measure the B.t.u. flow through a given area was now a reality.

W. M. McMyler, Jr., reported on a series of heat-transfer and combustion tests with various fuels, with and without secondary air, on a small domestic boiler. The Fuel Section of the Bureau of Mines had co-operated in the investigation. W. J. McConnell gave some data on the physiological reactions from high temperatures and humidities in still air.

At the heating session Wednesday morning there were five papers. "Insulation of Cold Surfaces to Prevent Sweating" was the subject treated by Leonard L. Barrett. The author established a mathematical basis for determining the thickness of insulation required to prevent sweating on the surface of the insulation under various conditions of temperature and humidity.

"Heating with Condenser Circulating Water," was the title of a paper by J. E. Williams describing the forced-circulation hot-water system at the Chase Metal Works plant.

Prof. F. E. Giesecke gave the results of a number of tests to determine the flow of heat through building walls, floors and ceilings by means of resistance wires.

In reviewing district heating progress in Boston, D. S. Boyden touched upon factors that had retarded the development of district heating, outlined the equipment of the stations and the load conditions, gave the steam service rates and compared the cost of purchased steam with private-plant operation.

At the final session S. R. Lewis outlined the contents of the new code on ventilation being prepared by the State of Wisconsin.

The voluminous report on ventilation recently made public by the New York State Commission received severe criticism, particularly that section favoring ventilation by means of hooded window inlets, radiators under the windows and gravity exhaust ducts. A committee was appointed to consider the proper action to take in this matter.

John Howatt gave an interesting survey of the heating and ventilating systems in use in the Chicago Public Schools. In general the later practice in Chicago school heating and ventilation is a plenum system with direct radiation only in offices, corridors, shops or other special rooms. Over 800 boilers are installed in the various plants, about 100 of the larger units being water-tube.

New Publications

Library of Power-Plant Practice (in 9 volumes). Edited by Terrell Croft, assisted by staff of contributors. Published by McGraw-Hill Book Co., Inc., New York, 1923. Red cloth with gold titles; 3,978 pages; 3,778 illustrations. Price of set, $19.50.

To satisfy the needs of the practical operating engineer, any new technical book or collection of books must meet three tests. In the first case it must explain the fundamental principles in such a way that they can be understood by a man not familiar with advanced mathematics. Secondly, it must show definitely how these principles can be applied in the every-day work of the engineer. In the third place it must be up to date, dealing with apparatus to be found in present-day plants. The third requirement would naturally be met by any new set of books written from the ground up and not as a revision of previous books. The first two requirements can be met only where there exists that rare combination of technical knowledge, ability to explain and familiarity with the viewpoint and the problems of the practical man. The Terrell Croft organization has repeatedly demonstrated that it possesses these qualifications.

The "Library of Power Plant Practice" is written both as a study course and as a practical reference library for the operating engineer. Each volume begins with the general principles, emphasizing them in proportion to the importance of their applications. The principles are then immediately applied to practical problems. In the limited space here available only the outstanding features of the various volumes can be mentioned. Vol. 1 (Steam boilers) describes the various types of boilers, shows how to figure stresses in riveted jointed and other parts, gives much information on boiler accessories, combustion, boiler settings, draft measurement, construction of breeching and stacks, etc. Vol. 2 (Steam-Engine Principles and Practice) is notable for the completeness of its instructions for valve setting. All modern types of valves are included. Other subjects treated are efficiency, testing, engine-room management, superheated steam, selection of units and lubrication. Vol. 3 (Steam Power Plant Auxiliaries and Accessories) gives needed attention to a branch of power-plant engineering that is of prime importance from the operating point of view. More than half of this book is devoted to pumps of which there are innumerable forms. Then feed-water heaters, economizers and condensers are treated in turn. Under condensers there is much valuable information on spray ponds and cooling towers. Other subjects covered by this book are steam piping, steam separators and traps. Vol. 4 (Steam-Turbine Principles and Practice) gives a similar treatment of the subject of steam turbines. This book contains much practical information about shafts, bearings, glands, governors, valves and other matters of particular interest to the operating man. Other subjects covered are bleeder turbines, testing, maintenance and economy. Vol. 5 (Machinery Foundations and Erection) is worthy of special note, because no previous book has ever covered this subject in the same way. Starting with the fundamental mechanical principles, it carries the reader to the numerous practical applications. Specific instructions are given not only for the construction of all types of foundations, with their anchor bolts, etc., but for the removal of machinery from flat cars and its transference to the foundation. In fact, it is hard to think of any detail in connection with the installation of a new piece of heavy machinery that has not been thoroughly covered by this book. The treatment is intensely practical throughout. The next two volumes, Nos. 6 and 7, constituting the two parts of the book on "Practical Heat," necessarily differ in method from the book on foundations, yet they are equally valuable. The subject of heat is a complicated one and can be mastered only by a thorough study of the elementary principles. This is given by the first volume, which at the same time makes extensive use of practical illustrations. Vol. 2 proceeds directly to a study of power plants, internal-combustion engines, building warming, refrigeration, etc. Vol. 8 (Electrical Machinery) is a practical explanation of the basic principles underlying the installation, operation, management, repair and selection of electrical machinery. The book contains much practical information on the methods of locating troubles and remedying them. Vol. 9 (Practical Mathematics by Palmer) is the only book in the series that is not new. Its inclusion in the library, however, is fully justified by the great success of previous editions.

A. I. & S. E. E. Mill, Mine and Manufacturer's Power Chart. By S. S. Wales, chief electrical engineer, Carnegie Steel Co. Published by the Association of Iron & Steel Electrical Engineers, Pittsburgh, Pa. Size, 15x24 in. Price, $1.

This chart provides a handy and convenient method of calculating the power required for all steel-mill operations and for mine hoists. It shows the percentage of power delivered at the generator terminals that may be available at the driven machine. For example, the chart shows at a glance that for each kilowatt (3,412 B.t.u.) delivered at the power-house switchboard, 2,037 B.t.u. is delivered to a reversing mill under one set of conditions, where under another method of transmission and transformation 1,897 B.t.u. only is available. To produce this power through a turbo-alternator requires delivering to the boilers 23,946 B.t.u. The heat units required to produce this power by all commercial types of power-plant equipment are given and also the quantity of fuel for all kinds that might be available around a steel mill. The power required per ton of finished materials has been tabulated as well as the blast-furnace gas available per ton of pig iron produced and the heat required to produce a ton of pig iron. These values have been obtained by averaging data from a large number of plants over a period of years. The load factor and idle time have been given consideration, as an endeavor has been made to show conditions that will ordinarily be encountered in average practice. For making approximate calculations, this chart should be of great assistance to all who have to deal with such problems in any industry.

Pulling Together. By John T. Broderick, with introduction by Charles P. Steinmetz, Ph.D. Published by Robson & Adee, Schenectady, N. Y. Cloth; 5 x 7½ in.; 167 pages. Price, $2.

This little book discusses, in the form of a conversation in the smoking compartment of a sleeper by a leader of industry, a traveling salesman and the author, the relations between employer and employee and the democratization of industry through employee representation in the operation of factories. Detail of method is sacrificed to a broad conception of the spirit of co-operation. To this, the sixth printing, a sequel dealing with the comments which the book has elicited, is added under the title of "Untouched Wealth." Its perusal would soften the acrimonies which mar the disposition of too many of the leaders on both sides of the question.

Preparation, Transportation, and Combustion of Powdered Coal. By John Blizard. Published (through the courtesy of the Canadian Department of Mines) by United States Bureau of Mines, Washington, D. C., 1923. Paper; 6x9 in.; 125 pages. Limited edition distribution free by Bureau of Mines, thereafter 50 cents a copy from Superintendent of Documents, Government Printing Office, Washington, D. C.

This is a readable and well-rounded discussion of the apparatus used and problems involved in the utilization of powdered coal. The subjects covered include: Characteristics of raw fuel, drying, pulverizing, distribution, feeders, mixers and burners, special uses of powdered coal, types of boilers, comparison with other methods of firing, costs and safety precautions. The bulletin is fully illustrated and should be of practical value to any engineer considering the adoption of powdered coal.

Scientific Papers of the Bureau of Standards No. 467—"Specific Volume of Saturated Ammonia Vapor" by C. S. Cragoe, Physicist, E. C. McKelvy, Chemist, G. F. O'Connor, Laboratory Assistant. Issued March 17, 1923, Price 5 cents. United States Government Printing Office, Wash., D. C.

Personal Mention

Elbert Allen, formerly chief engineer of the Philadelphia Rapid Transit Co., is now consulting engineer with Stone & Webster, Inc., of Boston.

Harold M. Toombs, formerly master mechanic with Morris & Co. before its purchase by Armour & Co., is now chief engineer for the Western Felt Works, Chicago, Ill.

C. B. Walter, vice-president and general manager of the Wright Austin Co., of Detroit, sailed early this month for Cuba to confer with his sales representatives in that country.

Joseph G. Worker, secretary of the Stoker Manufacturing Association and co-author of the book "Mechanical Stoker," has joined the organization of the American Engineering Co., Philadelphia, Pa., manufacturer of the Taylor mechanical stoker.

John T. Sharp, Jr., for several years superintendent of the Canton Light & Water Works Plant, Canton, Miss., has resigned to become manager of the Helena (Ark.) Gas & Electric Co., one of several properties owned by the Arkansas Utilities Co., of which J. S. M. Wharton is general manager.

Paul H. Brangs, formerly vice-president of the Heine Boiler Co., with offices at 11 Broadway, New York City, has notified his friends that he intends to devote the remainder of his life to foreign travel and recreation. His plans include a trip around the world, yachting, fishing and golf as well as a summer of rest by the seaside.

Society Affairs

The **A.I.E.E.** announce that at the annual business meeting held May 18, the following officers were elected for the administrative year beginning August 1: President, Harris J. Ryan, Stanford University, Calif.; Vice-presidents, H. E. Bussey, Atlanta, Ga.; S. E. M. Henderson, Toronto, Ontario; William F. James, Philadelphia; J. E. Macdonald, Los Angeles; Herbert S. Sands, Denver. Managers, H. P. Charlesworth, New York; William M. McConahey, Pittsburgh; W. K. Vanderpoel, Newark, N. J. Treasurer, George A. Hamilton, Elizabeth, N. J.

Business Notes

The Webster Manufacturing Co., of Chicago, announces the appointment of Robert T. Pierce as manager of its New York sales offices at 90 West St. He succeeds Glen N. Porter, whose death occurred March 31.

The Oilgear Co., Milwaukee, Wis., announces that W. D. Creider, formerly of the Federal Machinery Sales Co., of Chicago, Ill., has been appointed sales manager at Milwaukee, and A. L. Ellis, who has been in the Milwaukee office, is to be Eastern representative, with headquarters in New York City.

Coming Conventions

American Boiler Manufacturers' Association; H. N. Covell, 191 Dikeman St., Brooklyn, N. Y. Thirty-fifth Annual Convention at Hot Springs, Va., June 4-6.

American Institute of Electrical Engineers; F. L. Hutchinson, 29 West 39th St., New York City. Summer Convention at Swampscott, Mass., June 25-29.

American Order of Steam Engineers; W. J. Brice, 2126 S. 57th St., Philadelphia, Pa. 37th Annual Convention at Reading, Pa. (instead of Philadelphia, as formerly announced), June 4-8.

American Society for Testing Materials; C. L. Warwick, 1315 Spruce St., Philadelphia, Penn. Annual meeting at Atlantic City, N. J., June 25-30.

American Society of Mechanical Engineers, 29 W. 39th St., New York City. Spring meeting at Montreal, Canada, May 28-31.

Association of Iron & Steel Electrical Engineers; J. F. Kelly, 1007 Empire Bldg., Pittsburgh, Pa. Iron and Steel Exposition at Buffalo, N. Y., Sept. 24-28.

Canadian Association of Stationary Engineers; Gordon C. Keith, 51, Wellington St. West, Toronto, Canada. 34th Annual Convention at Toronto, Canada, June 25-28.

Electric Power Club; S. N. Clarkson, Kirby Bldg., Cleveland, Ohio. Annual meeting at Hot Springs, Va., June 11-14.

National Association of Practical Refrigerating Engineers; Ed. H. Fox, 914-25 East Jackson Blvd., Chicago. Fourteenth Annual Convention at Memphis, Dec. 12-16.

National Association of Stationary Engineers; Fred W. Raven, 417 South Dearborn St., Chicago, Ill. Annual convention and exhibition at Buffalo, N. Y., Sept. 10-15. Annual conventions and exhibitions of the State Associations scheduled as follows: **New Jersey**, at Trenton, N. J., June 1-3; Samuel Clark, 67 Columbia St., Jersey City, N. J. **Illinois**, at Springfield, Ill., June 6-9; F. W. Raven, 417 South Dearborn St., Chicago. **New England States Association**, at Manchester, N. H., Manchester hotel, July 12-14; Freeman L. Tyler, 32 Briggs St., Taunton, Mass. **Iowa**, at Mason City, Iowa, June 11-14; Abner Davis, Room 16, Waterhouse Block, Cedar Rapids, Iowa. **Ohio**, at Dayton, June 21-23; J. H. Weaver, 22 N. Gift St., Columbus, Ohio. **Pennsylvania**, at Buffalo, Sept. 9-10; J. N. Calvert, Crafton Sta., Pittsburgh, Pa. **New York**, at Buffalo, Sept. 9-10; W. T. Meinzer, Third St., near Warburton, Bayside, L. I., N. Y. **Minnesota**, at Duluth, Aug. 8-10; C. A. Nelson, 800 22d Ave. N. E., Minneapolis. **Connecticut**, at Waterbury, June 29-30; L. Van Der Eyk, 251 Wood St., Waterbury.

National District Heating Association, D. L. Gaskill, Greenville, Ohio. Annual convention at Cedar Point, Ohio. June 20-23.

National Electric Light Association; M. H. Aylesworth, 29 West 39th St., New York City. Annual meeting at New York City, June 4-8.

Ohio Electric Light Association, D. L. Gaskill, Greenville, Ohio. Annual convention at Cedar Point, Ohio, July 10-13.

Smoke Prevention Association; Frank Chambers, 111 N. Dearborn St., Chicago, Ill. Convention at Minneapolis, Minn., June 19-22.

Society for the Promotion of Engineering Education; F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa. Annual meeting at Cornell University, Ithaca, N. Y., June 20-23.

Stoker Manufacturers' Association; J. G. Worker, Eau Claire, Wis. Annual convention at Lake Placid Club, Essex Co., N. Y., May 29-31.

Universal Craftsman Council of Engineers; John F. Amos, P. O. Box 299, Rochester, N. Y. Convention at Rochester, N. Y., Aug. 7-11.

Trade Catalogs

Waterproofing: Methods and Materials—Gardiner & Lewis, Inc., 5 North La Salle St., Chicago, Ill. Karnak Bulletin No. 6, explains functions and methods of waterproofing.

Fuel Testing — Pittsburgh Testing Laboratory, Pittsburgh, Pa. Bulletin 30: The Value of Accurate Testing of Fuel, describes with photos the proper method of preparing a sample of coal or coke by hand.

Generators, Type E Engine Driven Alternating-Current — Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. Leaflet 2390-A, describes and illustrates the construction of these generators from 50 to 3,000 kva.

Lubricator, Keystone Manifold Safety —Keystone Lubricating Co., Philadelphia, Pa.—Booklet, "Eliminate Risk and Waste," describes and illustrates the methods of applying grease under high pressure with pipe-line distributions to more than one bearing.

Fuel Prices

BITUMINOUS COAL

The following table shows the trend of the spot steam market in various coals (mine run bases, f.o.b. mines):

Coal	Market Quoting	May 14, 1923	May 21, 1923
Pool 1,	New York	3.50–4.00	3.50–4.00
Smokeless,	Columbus	3.85–4.35	3.85–4.30
Clearfield,	Boston	2.25–3.25	2.25–3.00
Somerset,	Boston	2.75–3.50	2.75–3.25
Kanawha,	Columbus	2.00–2.40	2.00–2.40
Hocking,	Columbus	1.85–2.10	1.85–2.10
Pittsburgh No. 8	Cleveland	2.10–2.25	2.10–2.25
Franklin, Ill.,	Chicago	3.00–3.25	3.00–3.25
Central, Ill.,	Chicago	2.00–2.25	2.00–2.25
Ind. 4th Vein,	Chicago	2.75–3.00	2.75–3.00
West Ky.,¶	Louisville	1.85–2.00	1.85–2.00
S. E. Ky.,	Louisville	2.25–2.75	2.25–2.75
Big Seam,	Birmingham	1.85–2.25	1.85–2.25

FUEL OIL

(f.o.b. city unless otherwise specified)

New York—May 24, Port Arthur light oil, 22@25 deg. Baumé, 5⅜c. per gal.; 30@35 deg., 5¾c. per gal., f.o.b. Bayonne, N. J.

Chicago—May 5, 24@26 deg. Baumé, $2.12 per bbl.; 32@36 deg., $2.33 per bbl. tank cars.

Philadelphia—May 14, 26@28 deg. Baumé. Oklahoma, $1.10@$1.15 per bbl.; 30@34 deg., Oklahoma (group 3), 3⅛@3¼c. per gal.; 16@20 deg. Seaboard, $1.75@$1.90 per bbl.

St. Louis—May 18, tank-car lots, f.o.b. St. Louis; 30@32 deg. $1.90 per bbl., 26@28 deg., $1.80 per bbl.; 28@30 deg., $1.85 per bbl.; 32@36 deg., gas oil, 4¾c. per gal.; 36@40 deg., distillate 5½c. per gal.

Pittsburgh—May 15, f.o.b. local refinery, 30@34 deg., fuel oil, 5⅜c. per gal.; 36@40 deg., fuel oil, 5½c. per gal.; 34 deg., neutral, 9½c. per gal.

Dallas—May 19, f.o.b. local refinery, 26@30 deg., $1.57 per bbl.

New Plant Construction

PROPOSED WORK

Calif., Berkeley—The Pacific Gas & Electric Co., 445 Sutter St., San Francisco, is having plans prepared for the construction of a sub-station here. Estimated cost $50,000. Owner's Engineering Dept., Engrs.

Calif., Long Beach—D. B. Carlin, 45 Alboni St., is having preliminary plans prepared for the construction of an 8 story apartment building on East 1st St. Cost will exceed $750,000. W. H. Austin, 1st Natl. Bank Bldg., Long Beach, Archt.

Calif., Los Angeles—The city plans election June 5 to vote on a $35,000,000 bond issue for developing 250,000 hp. at the Boulder Canyon dam. $25,000,000 is to be used for development of hydro-electric energy at Boulder Canyon and the construction of the necessary transmission line and $10,000,000 for additional municipal distribution facilities.

Calif., Los Angeles—The F. E. Jones Mchy. Co., 1403 Sta. Fe., is in the market for a 25 hp. motor (used preferred).

Calif., Los Angeles—F. Siegel, 414 Chapman Bldg., plans to build a 14 story hotel on Figueroa St. Cost will exceed $500,000. Engineer or architect not selected.

Calif., Los Angeles—The Standard Oil Co., Standard Oil Bldg., San Francisco, is having plans prepared for the construction of an 8 story office building on Hope and 10th Sts., here. Estimated cost $1,000,000. H. J. Brunnier, Sharon Bldg., San Francisco, Engr. G. W. Kelham, Sharon Bldg., San Francisco, Archt. Equipment detail not reported.

Calif., Napa—The city is having plans prepared for the construction of diversion dam, pressure break, chlorination house and well, etc., in connection with Milliken Canyon water project. Cost will exceed $15,000. A. Kempkey, Hobart Bldg., San Francisco, Consult. Engr.

Calif., San Jose—The County of Santa Clara is having plans prepared for the construction of a power house on the county hospital grounds. Estimated cost $90,000. Binder & Curtis, 255½ South 1st St., San Jose, Archts.

Conn., New Britain—The Amer. Hardware Corp., P. and F. Corbin Division, Park St., has had plans prepared for the construction of a 2 story, 15 x 80 ft. power house. Estimated cost $50,000. Private plans. The owner is in the market for two turbines.

D. C., Wash.—M. Cafritz, 913 15th St., is having plans prepared for the construction of an apartment hotel at K and 14th Sts. Estimated cost $1,300,000. MacNeil & MacNeil, 14 West 45th St., New York, Archts. Equipment detail not reported.

D. C., Wash.—A. L. Flint, Genl. Purch. Officer of the Panama Canal, will receive bids until June 4 for furnishing electrical equipment for towing locomotives.

Fla., New Smyrna—The city, G. J. Ott, Mgr., is receiving bids for the construction of an addition to present power plant consisting of a 300 hp. electrical unit, 200 kw. d.c. Estimated cost $35,000. C. Brooks, New Smyrna, Engr. Equipment includes 300 hp. air combustion engine and 250 kva. generator.

Ill., Chicago—R. S. De Golier, Archt., 7 South Dearborn St., is receiving bids for the construction of a 9 story addition to apartment building, including steam heating system, at 808 Junior Terrace, for the Terrace Apartment Hotel Co., 4300 Claredon Ave. Estimated cost $500,000.

Ill., Chicago—The Rettig Bldg. Corp., c/o E. E. Hall, Archt., 123 West Madison St., is having plans prepared for the construction of a 10 story, 124 x 269 ft. apartment building, including steam heating system, on Stony Island Ave., 66th and 67th Sts. Estimated cost $2,500,000.

Ill., Chicago—The Union Stock Yards, 38 South Dearborn St., are having plans prepared for the construction of an 8 story, 52 x 240 ft. live stock exchange building, including steam heating system, at the Union Stock Yards. Estimated cost $1,000,000. A. Epstein, 2007 West Pershing Rd., Archt.

Ill., Chicago—C. W. Westerlind, Archt., 179 West Washington St., is receiving bids for the construction of a 3 story, 150 x 245 ft. apartment building, including steam heating system, on Palmer and Richmond Sts., for Ives Bros., c/o Architect. Estimated cost $650,000.

Ill., Edwardsville—The Levee & Drainage Dist. Assn., Court House, is having plans prepared for drainage work and pump house. Estimated cost $75,000. S. C. Morgan, Edwardsville, Engr.

Ill., Granite City—The Commonwealth Steel Co. is having plans prepared for the construction of a 1 and 2 story steel plant, including hearth furnace, 75 ton daily capacity; coke oven building; metal pattern shop; additions to foundry and core room and extension to power plant. Estimated cost $1,000,000. Private plans.

Ind., New Harmony—The City Council is in the market for steam power outfit direct connected to a 100 kw. d.c. generator.

Ia., Oskaloosa—The Bd. of Waterworks Trustees will receive bids until June 1 for the construction of a 2,000,000 gal. rapid mechanical filtration plant, including equipment, also for a control dam across the new channel of the Skunk River. Brown & Cook, 121 East 2nd St., Ottumwa, Engrs.

Kan., Arkansas City—The G. F. Sicks Machine Co., 204 North Summit St., is in the market for one 5 hp., 220 volt, 3 phase, 60 cycle, 1,700 to 1,800 r.p.m. and one 50 hp. 220 volt, 3 phase, 60 cycle motor.

Kan., Eureka—R. I. Frost is in the market for a 25 hp. motor.

Ky., Ashland—The Hotel Buckingham plans to build an 11 story hotel to contain 250 rooms. Estimated cost $1,000,000. Engineer or architect not selected.

Ky., Dawson Springs—The United States Veteran's Bureau, Maintenance & Repair Sub-Division, Room 790, Arlington Bldg., will receive bids until June 15, for the construction of a recreation building and six duplex officers' quarters, including hot water heating, electric installation, etc., at the United States Veterans Hospital 79, here. F. T. Hines, Dir.

Ky., Louisville—F. G. Breslin, 32nd and Market Sts., plans to build an 18 story, 95 x 175 ft. office building on 3rd St. and Broadway. Estimated cost $1,500,000. Engineer or architect not selected.

Ky., Louisville—The Downard-Manning Coal Co., 1024 Inter-Southern Bldg., plans the installation of electrical equipment and mining machinery at its mines. Estimated cost $50,000.

Ky., Louisville—W. Heyburn, 403 West Ormsby St., is having plans prepared for the construction of a 10 or 12 story department store on 4th St. near Broadway. Estimated cost $1,000,000. Joseph & Joseph, Francis Bldg., Louisville, Engrs. and Archts. Equipment detail not reported.

Ky., Louisville—The Norton Memorial Hospital, 3rd St., D. A. Keller, Chn. Hospital Com., plans to build an 8 to 12 story hospital on 3rd and Oak Sts. Estimated cost $1,500,000. Engineer or architect not selected.

Ky., Louisville—Office of U. S. Engineers, P. O. Box 72, L. S. Ehrman, Purch. Agt., is in the market for one 10 hp., 550 volt vertical shaft motor.

Ky., Louisville—H. G. Talamini, W. G. Apartments, plans to build a 10 story, 100 x 200 ft. apartment and store building on 3rd and York Sts. Estimated cost $1,000,000. Engineer or architect not selected.

Ky., Paducah—The Paducah Electric Co. plans improvements and additions to its power plant. Estimated cost $300,000. The owner is in the market for boilers, coal handling machinery and auxiliary equipment.

Md., Baltimore—The Bd. of Awards, c/o City Register, City Hall, will receive bids until May 31 for two 8,000,000 gal. motor driven centrifugal pumps and electrical equipment for the Druid pumping station.

Md., Baltimore—The Standard Sanitary Mfg. Co., Bessemer Bldg., Pittsburgh, Pa., is having plans prepared for the construction of a group of manufacturing buildings on 5th Ave., here. Estimated cost $2,500,000. S. Diescher & Sons, Farm Bldg., Pittsburgh, Pa., Engrs.

Mass., Boston—The Dept. of Pub. Wks., J. A. Rourke, Comr., plans to build a police headquarters on Pemberton Sq. Estimated cost $1,000,000. Engineer or architect not selected.

Mich., Detroit—The Ittmans & Dean Co., 1255 Griswold St., is having plans prepared for the construction of a 2 story, 71 x 285 ft. ice manufacturing plant on Broad St. Estimated cost $50,000. Private plans. The owner is in the market for equipment, piping, etc.

Mich., Detroit — The Public Lighting Comn., Atwater St., F. Misterdky, Supt., received bids for four 20,000 kw. turbo-units for new power plant from Genl. Electric Co., 1501 Dime Bank, Detroit, $1,258,000; Westinghouse Electric & Mfg. Co., 1535 6th St., $1,254,000; Allis-Chalmers Mfg. Co., West Allis St., Milwaukee, Wis., $1,247,000.

Minn., St. Peter—The State Bd. of Control, D. F. Mullen, Secy., Capitol, St. Paul, is having plans prepared for remodeling power plant at the State Hospital for Insane, here. C. L. Pillsbury Co., 716 Capital Bank Bldg., St. Paul, Engrs. C. H. Johnston, 715 Capital Bank Bldg., St. Paul, Archt.

Miss., Vicksburg—The Office of 3rd Mississippi River Dist., P. O. Box 404, will receive bids until June 15 for eight marine boilers.

Mo., Bolivar—The city is having preliminary surveys made and will soon hold an election to vote on a bond issue for improvements to electric lighting system and the construction of a complete sewer system. A. L. Archer & Co., 609 New England Bank Bldg., Kansas City, Engrs.

Mo., Kansas City—The Jenkins Music Co., 1013 Walnut St., is having preliminary plans prepared for the construction of a 10 story, business building. Estimated cost $500,000. C. A. Smith, 612 Finance Bldg., Archt. Equipment detail not reported.

Mo., St. Louis—The Coronado Hotel Co., International Life Bldg., has had plans prepared for the construction of a 10 story, 177 x 206 ft. hotel on Spring Ave. Estimated cost $2,000,000. P. J. Bradshaw, International Life Bldg, Archt. Equipment detail not reported.

N. J., Newark—The Permanent Industrial Exposition, c/o F. Grad, Archt., 245 Springfield Ave., is having plans prepared for the construction of a 200 x 400 ft. exposition building. Estimated cost $2,000,000. Equipment detail not reported.

N. Y., Brooklyn—The Bd. Educ., 500 Park Ave., New York, will soon receive bids for the construction of a 5 story school building, including steam heating system, on Dahill Rd., here. Estimated cost $1,075,000. W. H. Gompert, Flatbush Ave. Ext. and Concord St., Brooklyn, Engr. and Archt. Noted Apr. 17.

N. Y., Buffalo—The Bd. Educ., 1400 Telephone Bldg., will receive bids until June 4, for vocational school equipment including motors and air compressor.

N. Y., Ithaca—Cornell University is having revised plans prepared for the construction of a recreation building. Estimated cost $1,000,000. Delano & Aldrich, 126 East 38th St., New York, Engrs. and Archts. Noted July 11.

N. Y., New York—The 617 5th Ave. Corp., c/o Margon & Glaser, Archts., 2804 3rd Ave., will build a 45 x 100 ft. office building at 617 5th Ave. Estimated cost $500,000. Equipment detail not reported.

N. Y., Nunda—The village is in the market for pumping station equipment for waterworks, to replace that destroyed by fire. Estimated cost $5,000.

N. Y., Poughkeepsie—The Bd. of Public Wks., Eastman Park Mansion, will receive bids until June 7 for the construction of a sewage pumping station. Hazen & Whipple, 25 West 43rd St., New York, Consit. Engrs.

N. C. Kinston—The city sold $200,000 bonds, to be used for remodeling existing buildings, adding additional rooms and installing new heating plant for both white and negro schools.

N. C., Kinston — The Caswell Training School, C. B. McNairy, Supt., will receive bids until June 5 for the construction of a hospital, boys industrial building, girls industrial building, laundry, cold storage building, etc., including plumbing and electrical wiring. Other mechanical equipment under separate contract. H. A. Underwood, 916 Commercial Bank Bldg., Raleigh, Engr.

N. C., Walkertown — The Walkertown Chair Co. will build a 1 story, 50 x 100 ft. chair factory, also engine room, boiler room and dry kiln.

Ohio, Canton—The Pythian Castle Co. plans to build a 7 story addition to double capacity of Hotel Northern on 6th and Market Sts. Estimated cost $300,000.

Ohio, Cleveland—The Association Bldg. Co., c/o G. W. Crile, East 93rd St. and Euclid Ave., will soon award the contract for the construction of a 6 story, 50 x 164 ft. hospital, including steam heating system. Estimated cost $400,000. Ellerbe & Co., Endicott Bldg., St. Paul, Minn., Archts.

Ohio, Cleveland—The Cleveland Railway Co., Hanna Bldg., has had plans prepared for the construction of several 1 story, 54 x 62 ft. automatic substations. Estimated cost $1,000,000. L. P. Bale, c/o owner, Archt. The contract for equipment has been awarded to the Westinghouse Electric & Mfg. Co., Swetland Bldg., Cleveland.

Ohio, Cleveland—The city, Purch. Division, City Hall, is in the market for one 1,000 gal. capacity steam turbine driven centrifugal pump.

Ohio, Columbus—The Dept. of Welfare, 9th and Oak Sts., c/o J. E. Clark, is in the market for a brick plant at Junction City, also one 300 hp. engine and 2 tubular boilers.

Okla., McAlester—The city voted $375,000 bonds for rebuilding dam at Lake McHowe, new pipe line and pumping equipment, making a water supply of 6,000,000,000 gal. E. T. Archer & Co., New England Bldg., Kansas City, Mo., Engr.

Okla., Oklahoma City—The Physicians & Surgeons Co. & Nurses Exch., 41 Continental Bldg., plans to build a 9 story, 125 x 140 ft. office building on Robinson and 1st Sts. Estimated cost $1,000,000. Engineer or architect not selected.

Tenn., Milan—The city council plans additions and extensions to municipal light and power plant. Estimated cost $40,000.

Tex., Dallas—De Witt & Lemmon, Archts., 507 S. W. Life Bldg., will receive bids until June 1 for the construction of first unit of 6 story sanitarium, including steam heating system, on Ballard and Grover Sts., for the North Texas Conference, M. E. Church South, 807 Mercantile Bldg., J. H. Groseclose, Supt. Estimated cost $400,000. Noted May 15.

Tex., Fort Worth—The City Comn. will receive bids until about June 5 for two electrically driven pumps, 2,000,000 g.p.d.; one gasoline engine pump, 3,000,000 g.p.d.; one 50,000 gal. steel tank; one 333,000 gal. concrete sump; construction of a 27 x 38 ft. pump house for South Side booster station. Estimated cost $60,000. D. L. Lewis, City Engr. J. B. Hawley, Cotton Exch., Fort Worth, Consult. Engr.

Tex., Wichita Falls—G. Dashner, R. D. Box 991, is in the market for a 100 hp. gas engine for natural gas.

W. Va., Oak Hill—The Oak Hill Water Co., R. R. Thomas, Pres., is in the market for electrically operated pumping machinery with auxiliary equipment. Cost will exceed $5,000.

Wis., Ellis Junction (Crivitz, P. O.)—The Wisconsin Public Service Co., 559 Marshall St., Milwaukee, is having plans prepared for the construction of 5 mi. of high voltage transmission line from here to High Falls, several steel tainter gates and two steel penstocks for dam. Mead & Seastone, Journal Bldg., Madison, Engrs.

Wis., Fond du Lac—St. Agnes Hospital, M. Marcella, Genl. Superior, 390 East Division St., is having preliminary plans prepared for the construction of a power house. Estimated cost $45,000. R. E. Schmidt, Garden & Martin, 104 South Michigan Ave., Chicago, Ill., Engrs. New boilers and pumps will be required.

Wis., Milwaukee—The Chicago & Northwestern Ry., 226 West Jackson Blvd., Chicago, Ill., is receiving bids for the construction of a coaling station. Estimated cost $45,000. Coal handling machinery will be required.

Wis., Reeseville—The village, A. C. Buss, Clk., will receive bids until June 1 for the construction of a 50,000 gal. steel tank with 116 ft. tower (alternate bids on 60,000 gal. tank, same height); two pumping units and motors; drilling 12 in. well and casing; 20,000 gal. reservoir; c.i. pipe water mains; sewers; gate valves; hydrants; septic tank, etc. E. B. Parsons, Jefferson, Engr. Noted May 8.

Wis., Wausau—The Bellis Hotel Co., M. G. Bellis, Pres., 3rd and Scott Sts., is having plans prepared for the construction of a 3 story, 50 x 120 ft. hotel on 2nd St. Estimated cost $150 000. Oppenhamer & Obel, Archts. Refrigeration machinery, ice machine, etc., will be required.

Ontario—The Provincial Government has voted $12,687,000 to the Hydro-Electric Power Comn. of Ontario, A. Beck, Chmn., 190 University Ave., Toronto, to cover work for this year as follows: (1) Niagara system, installation of additional machinery at Queenston, Ont., completion of Queenston plant and new transmission lines, $9,850,000. (2) Muskoka system, additional equipment and plant additions, $360,000. (3) Rideau system, maintenance and repairs, $20,000. (4) Thunder Bay system, new units at Cameron Falls, Nipegon River, transmission lines, etc., $1,016,000. (5) Central Ontario system, largely to cover new plant at dam No. 8 Trent River, $1,375,000. (6) Nipissing system, storage works and auxiliary, $17,000. (7) Essex system largely transmission lines, $50,000. (8) Investigation of a second Queenston-Chippewa development by owner's engineers, $50,000. F. A. Gaby, c/o Owners, Ch. Engr.

Ont., Hamilton—The city, S. H. Kent, City Hall, Clk., will receive bids until June 6 for one horizontal centrifugal sewage pump, 130 imp. g.p.m. against 67 ft. head, direct connected to a 10 hp. motor with automatic starter. W. L. McFaul, City Hall, Engr.

Ont., Orangeville—The Engineering & Radio Supplies, Ltd., have purchased hydro-electric plant from the Cataract Electric Co. and plans to increase the output from 800 to 3,000 hp. Additional turbines, generators and electrical equipment will be required.

Ont., Ottawa—The city council is having plans prepared for the construction of a central steam heating plant, using soft coal and screenings, for the city buildings. A. F. Macallum, City Hall, City Engr.

Ont., Toronto—The Genl. Bldg. Corp., 366 Adelaide St., W., plans to build a 14 story office building, including steam heating system, elevators, etc., on King and York Sts. Estimated cost $1,000,000.

Ont., Walkerton—F. B. James, Archt., County Bldg., will receive bids until June 18, for the construction of a central heating plant, including steam vacuum system, horizontal tubular boilers and vacuum pump for the county buildings here. Estimated cost $50,000.

Que., Farnham—The Corporation of Farnham, J. E. Lefebre, Secy. and Treas., will soon be in the market for additional pumping equipment.

New Zealand—The Public Works Tenders Board, Wellington, will receive bids until Feb. 28, 1924, for headworks for Arapuni electric power scheme, Section 1. Work includes the construction of a diversion tunnel, concrete dam, spillway, and penstock intake, excavation of a headrace, and the supply, delivery, and erection of valves, gates and screens.

N. S., Amherst—The town is in the market for equipment for hydro-electric plant.

CONTRACTS AWARDED

Ark., Pine Bluff—The Arkansas Light & Power Co., awarded the contract for the construction of the Remmel dam and hydro-electric power station on the Ouachita river between Malvern and Hot Springs. Estimated cost $1,500,000. This dam and power station will develop 15,000 hydro-electric horsepower and is the first of a series of three planned for the development of 120,000 hp.

Calif., Los Angeles—H. Rivers, et. al., 414 South Irving Blvd., awarded the contract for the construction of an 11 story hotel and stores building on Columbia and 6th Sts., to the Arndorff Klapper Gow Co., 625 Bank of Italy Bldg., about $400,000. Equipment detail not reported.

Calif., San Francisco—The Western States Life Insurance Co., Market and 6th Sts., awarded the contract for the construction of concrete work of 15 story office building on Stevenson and 6th Sts. to Barrett & Hilp, 918 Harrison St., San Francisco. About $125,000, total cost $800,000. Other contracts are not yet awarded. Reid Bros., 105 Montgomery St., San Francisco, Archts. Equipment detail not reported. Noted Nov. 21, 1922.

Conn., New Haven—The New Haven Gas Light Co., 80 Crown St., awarded the contract for the construction of a 66 x 135 ft. boiler house on East Chapel St., to the Standard Constr. Co., 153 Court St. Estimated cost $50,000. Contract for 8 boilers has been awarded. Noted Dec. 26, 1922.

Conn., New Haven—Yale University, J. R. Angell, Pres., awarded the contract for the construction of a 3 story, 175 x 243 ft. museum on Whitney Ave., to Sperry & Treat Co., 39 Church St. lighting system to the Plymouth Electric Co. Estimated cost $1,000,000. Contract for steam heating and ventilating system not yet awarded.

D. C., Wash.—W. S. Phillips, 15th and K Sts. N. W. awarded the contract for the construction of an apartment house on Argonne Pl. to the Weller Constr. Co., 816 14th St., N. W., Wash. Estimated cost $2,000,000. Equipment detail not reported.

Ill., Chicago—The Chelsea Hotel Co., 4750 Sheridan Rd., awarded the contract for the construction of a 10 story, 116 x 130 ft. hotel at 920 Wilson Ave. to the McLennan Constr. Co., 400 North Michigan Ave. Estimated cost $660,000. Steam heating system will be installed.

Ill., Chicago—S. Earling, 140 South Dearborn St., awarded the contract for the construction of a 5 story, 65 x 150 ft. hotel at 5410 Kenmore Ave. to the Antrill Constr. Co., 1106 Leland Ave., Chicago. Estimated cost $250,000. Steam heating system will be installed.

Mich., Detroit—The Women's City Club, 141 Bayley Ave., awarded the contract for the construction of a 6 and 9 story, 90 x 120 ft. club house, including steam heating equipment, on Park and Elizabeth Sts., to the Walbridge-Aldinger Co., 2356 Penobscot Bldg., Detroit. Estimated cost $500,000. Noted Mar. 13.

Mich., Lansing—The Michigan Butter & Egg Co., 701 East Kalamazoo St., awarded the contract for the construction of a 3 story, 50 x 50 ft. cold storage plant to G. Hagemerr, Lansing. Estimated cost $50,000. The owner is in the market for cold storage equipment.

N. Y., Brooklyn—Mengel & Larkin, Archts., 81 Fulton St., awarded the contract for the construction of a 6 story, 25 x 160 ft. apartment house on St. Marks and New York Aves. to G. M. Seglin, Inc., 110 East 42nd St., New York. Estimated cost $2,000,000. Owner's name withheld. Equipment detail not reported.

N. Y., White Plains—The White Plains Hospital, New York Post Rd., awarded the contract for the construction of a 3 story addition to its hospital to the W. E. Green Co., 70 East 45th St., New York. Estimated cost $250,000. Equipment detail not reported.

N. C., Mooresville—The city awarded the contract for the construction of a pumping station, filter house, auxiliary station, coagulating basin, storage reservoir, laying 5 mi. c. i. pipe lines and 5 mi. of 2,200 volt electric transmission lines for pumping purposes to Guion & Withers, Gastonia, $162,000; filter equipment to Tucker & Laxton, Realty Bldg., Charlotte; furnishing pipe, to Glamorgan Pipe & Fdry. Co., 98 Adams St., Lynchburg, Va.; pumps, Morris Machine Wks., Baldwinsville, N. Y.; wash water tanks, Chicago Bridge & Iron Wks., 608 South Dearborn St., Chicago; valves, Grinnell Co., Hartman Bldg., Columbus, Ohio.

Ohio, Columbus—The Jeffrey Manufacturing Co., East First Ave., awarded the contract for the construction of a 4 story office building, including small power plant for heating, also a chemical laboratory, at 4th St. and 1st Ave., to Stone & Webster, Inc., 147 Milk St., Boston, Mass.

Ohio, Toledo—The Home Savings Bank Co., M. Miller, Pres., Madison and Superior Sts., awarded the contract for the construction of a 9 story, 59 x 119 ft. bank and office building on Huron and Madison Sts., to the Spieker Construction Co., Elm and Utica Sts. Estimated cost $1,000,000. Steam heating system will be installed. Noted Mar. 27.

Okla., Weatherford—The city awarded the contract for one 260 and one 190 hp. Diesel engine generator sets complete with wiring, to the Fulton Iron Works, 1259 Delaware St., St. Louis, Mo., $42,606. Noted Mar. 31.

Pa., Erie—The Erie County Electric Co. awarded the contract for the construction of an addition to its power plant to the Blair Constr. Co., Erie. Estimated cost $25,000. Noted Apr. 3.

Ont., Toronto—The R. Simpson Co., Ltd., Yonge and Queen Sts., awarded the general contract for the construction of a 6 and 8 story, 50 x 210 ft. addition to its department store to the Jackson Lewis Constr. Co., Ltd., Ryne Bldg.; structural steel to McGregor & McIntyre, Ltd., 1139 Shaw St. Estimated cost $1,000,000. Contracts for steam heating system, electric light, elevators, escalators, conveyors, etc., have not been awarded yet.

Bulgaria—The Bank of Agriculture of Bulgaria awarded the contract for the construction of a system of grain elevators of the American type, including construction and equipment of central power stations, drying plants, wharves, etc., to the MacDonald Eng. Co., 53 West Jackson Blvd., Chicago, Ill. Estimated cost $10,000,000.